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FINAL REPORT

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for

Defense Civil Preparedness Agency
Washington, D.C. 20301

Contract No. DCPA01-77-C-0230
Work Unit No. 2422E

Dr. William Wisecup, COTR

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by

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This work was conducted in support of Crisis Relocation Planning (CRP), a comprehensive effort by the Defense Civil Preparedness Agency to prepare contingency plans for the relocation of population from high-risk areas to protect them from the combined blast and radiation effects of nuclear weapons. This program considered one of the most important functions — sewage treatment — in the host areas. With the possible exception of an adequate safe water system, no other municipal function

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is more critical for public health, especially during emergency situations in host areas where the population may increase as much as five fold.

This report is presented in three parts. Part I, the technical report, provides background material, references, and the rationale behind the development of the manual, which is Part II. Also discussed is the field testing phase including observations and conclusions obtained from this testing. This part of the report may be of interest to Defense Civil Preparedness Agency and state Civil Defense personnel as well as to sewage plant operators.

Part II, a sewage treatment operations manual for Crisis Relocation(CR), is directed primarily at sewage treatment plant operators. The manual is organized around the various treatment processes. Following a brief description of each process are worksheets detailing each individual calculation needed to estimate performance of the different processes and identify trouble areas within the plant. The worksheets provide a step-by-step analysis of present operating conditions, the projected operational loadings during CR, and the effect of these increased loadings on process operations. Discussion of operational problems likely to occur during CR is followed by a detailed troubleshooting guide and brief discussion of laboratory tests that will be most useful in analyzing potential problems associated with CR.

A summary worksheet is provided which helps the user categorize the severity of potential problems associated with each process for a particular plant. A variety of load reduction measures are described, and some sample forms dealing with various logistical arrangements pertinent to CR are included.

Part III deals with the disposal of wastes in non-sewered areas. This will be a significant problem during CR for those relocation host areas not serviced by a sewage treatment plant. Topics discussed include various types of disposal, public health issues, and proper disposal and control measures. This part of the report may be of interest to local civil defense personnel including local mayors, chiefs of police, fire chiefs as well as Defense Civil Preparedness Agency and state Civil Defense personnel.

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Contract No. DCPA01-77-C-0230
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Dr. William Wisecup, COTR

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SUMMARY REPORT

This work was conducted in support of Crisis Relocation Planning (CRP), a comprehensive effort by the Defense Civil Preparedness Agency to prepare contingency plans for the relocation of population from high-risk areas to protect them from the combined blast and radiation effects of nuclear weapons. This program considered one of the most important support functions — sewage treatment — in the host areas. With the possible exception of an adequate safe water system, no other municipal function is more critical for the protection of the health of the population. This is especially true during emergency situations in host areas where the population may be increased as much as five fold.

This report is presented in three parts. Part I is the technical report which provides background material, references, and the rationale behind the development of the manual which is Part II. Also discussed is the field testing phase including observations and conclusions obtained from this testing. This part of the report may be of interest to Defense Civil Preparedness Agency and State Civil Defense personnel as well as to sewage treatment plant operators.

Part II is a sewage treatment operations manual for Crisis Relocation (CR). This manual is organized around the various treatment processes. First there is a brief description of each process; then, to aid the plant operators, worksheets have been set up to detail each individual calculation that is needed to estimate performance of the different processes and identify trouble areas within the plant. A brief worksheet description precedes each worksheet. The worksheets are arranged to provide a step-by-step analysis of present operating conditions, the projected operational loadings during CR, and the effect of these increased loadings on process operations. Following each

worksheet there is a discussion of operational problems likely to occur during CR, followed by a detailed troubleshooting guide and brief discussion of laboratory tests that will be most useful in analyzing potential problems associated with CR.

Following the sections on treatment processes, a summary worksheet is provided which helps the user categorize the severity of potential problems associated with each process for a particular plant. The next section describes a variety of load reduction measures which can be implemented depending on the nature of the anticipated problem. The manual concludes with some sample forms dealing with various logistical arrangements pertinent to CR. Part II may be of interest to Defense Civil Preparedness Agency and State Civil Defense personnel but is primarily directed at sewage treatment plant operators.

Part III deals with the disposal of wastes in non-sewered areas. This will be a significant problem during CR since many of the relocation host areas will not be serviced by a sewage treatment plant. Topics discussed include various types of disposal, public health issues, and proper disposal and control measures. This part of the report may be of interest to local civil defense personnel including local mayors, chiefs of police, fire chiefs as well as Defense Civil Preparedness Agency and State Civil Defense personnel.

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EMERGENCY SEWAGE PROCEDURES

DURING

CRISIS RELOCATION

Part I-Technical Report

prepared for

Defense Civil Preparedness Agency
Washington, D.C.

Contract No. DCPA01-77-C-0230
Work Unit 2422E

Dr. William Wisecup, COTR

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Section 1
INTRODUCTION

CRISIS RELOCATION PLANNING

Crisis Relocation Planning (CRP) is a comprehensive effort by the Defense Civil Preparedness Agency to prepare contingency plans for the relocation of population from high-risk areas to protect them from the combined blast and radiation effects of nuclear weapons. This concept assumes that a nuclear attack on the United States would be preceded by a crisis buildup phase allowing sufficient time for protective action to be taken, such as the relocation of residents from possible target areas to areas of low risk, and the preparation of facilities and services for taking care of the relocated population of the host areas. The relocation time will be very short, i.e., probably a few days. While this report period does allow sufficient time for relocation and some preparation for providing services and protection for the relocated population, it most certainly does not allow time for planning. Thus, all necessary planning for the various operating and support functions must be completed prior to the crisis period.

The concept of CRP wherein concentrated populations of metropolitan areas are evacuated creates problems for both the cities so evacuated and for the receiving host areas. Many aspects of this problem have already been considered in previous studies of CRP and, as the concept becomes more viable, it becomes necessary to consider in greater detail the basic support functions that will be required in the event such planning is implemented. A number of support functions will be required such as transportation requirements during and following relocation, revision of existing food networks, provision of fire and police protection, etc.

One of the most important support functions not previously studied, and which is the subject of this report and associated manual, is sewage treatment. With the possible exception of an adequate safe water system, no other municipal function is more critical for the protection of the health of the population during CR.* This will be especially true during emergency situations in host areas, when the population may be increased as much as five fold.

OVERVIEW OF PROBLEM

The major concern of those dealing with emergency sewage procedures during CR or of those planning for CR is the potential public health problem associated with the transmission of diseases. The primary objective of any sewage disposal or treatment system is the prevention of the spread of disease. A properly designed and operated system will accomplish this objective. However, during CR, increased waste production can overtax sewerage facilities. Unless adequate measures are taken, this could lead to less efficient pathogen removal and destruction creating a greater potential for the transmission of enteric diseases. Private sewerage systems, such as septic tanks, also may be overloaded by the influx of relocatees, causing an added strain on these systems.

The transmission of disease from sewage usually occurs by either of two mechanisms: contamination of a water supply by waterborne organisms or contamination of food by vectorborne organisms (usually flies). Transmission via water is the usual mechanism of contamination and can occur due to the mixing of sewage effluents with surface receiving waters or due to the contamination of ground waters by seepage from lagoons, land disposal sites, septic tanks or privies.

The potential for transmission of waterborne diseases is a function of the incidence of a particular disease in the population served by a water

* Throughout this report, the crisis relocation period will be referred to as CR. Similarly, pre-CR is used to refer to operations prior to CR.

and sewerage system. Public health data show that gastro-intestinal diseases, shigellosis, and hepatitis are the major waterborne diseases of concern transmitted by drinking water with typhoid having the lowest incidence (see Table I-13). Fortunately, most of the typhoid carriers are documented with public health officials, thus allowing special planning for the relocation of these individuals to minimize the public health impact of their relocation. Other known diseases which may be spread through wastewater discharges are cholera, polio, and tuberculosis.

As shown in Table I-13, page I-60, the incidence of waterborne disease outbreaks appears to be on the increase. This phenomenon could possibly be due to better reporting of disease outbreaks; however, a movement from urban to rural areas is also likely to be a partial cause of this increase. Berg (Ref. 1) notes that "private and semi-private water supplies have accounted for about 70 percent of recognized waterborne outbreaks in the U.S. at least since 1938" while 76-90 percent of all cases of waterborne diseases are associated with public systems. Berg also notes that "In more than 50 percent of the outbreaks associated with private or semi-public water supplies, visitors or tourists were involved rather than regular users, suggesting the possibility that very many small outbreaks involving regular users go undetected until illness among visitors provides a dramatic and easily recognized epidemiologic clue. It appears likely, therefore, that private and semi-public water supplies are responsible for an even higher proportion of cases and of outbreaks than has thus far been recorded."

Craun (Ref. 2) notes that about 57% of all waterborne disease outbreaks in private and semi-public systems during 1946-70 were caused by contaminated untreated ground water with the overflow or seepage of sewage being the primary source of contamination. In a series of five regional studies, EPA (Ref. 3) noted that septic tanks and cesspools rank highest in total volume of wastewater discharged directly to ground water and were the most frequently reported sources of contamination. The implications of the above statistics for CR are obvious. With massive, rapid influxes of people into rural areas

which rely primarily on septic tanks and cesspools for waste disposal and untreated groundwater as the source of drinking water, the potential for waterborne disease outbreaks will be significantly increased. For this reason, a separate Part III is included in this report dealing specifically with waste disposal in non-sewered areas.

In addition to the public health issues in non-sewered areas, an increase in population in sewered host areas would increase the quantities of the four major inputs of sewage treatment systems which are:

- o Hydraulic load
- o Organic load
- o Solids load
- o Inorganic nutrient load

In a sewage treatment system that is insufficient to handle the increased population, the following would likely occur:

An increase in the hydraulic load would decrease the detention time throughout the existing plant causing a decrease in the efficiency of sedimentation tanks due to increased overflow rates. Disinfection of the effluent would be decreased because of reduced detention time in the chlorine contact tank; and the level of biological treatment would decrease because of reduced contact time between organic wastes and the treating micro-organisms.

An increase in organic load would increase the amount of oxygen-demanding material entering the plant and would create additional solids production from the biological treatment process. This would overload the solids treatment and disposal process. Increased organic loads would also increase the oxygen demand by the biological treatment process. If these demands cannot be met, the biological system would be stressed causing odors, and most important, causing an increase in the biochemical oxygen demand (BOD) load on the receiving waters.

An increase in solids load would add to the increased biological solids production from the increased organic load to further stress the solids treatment and disposal system. Failure of this system would result in the production of large quantities of untreated sewage solids which would represent a significant reservoir of pathogenic organisms in the host area.

An increase in the inorganic nutrient load would increase eutrophication in the receiving water, however, the consequences of this are primarily aesthetic and would not be significant unless the relocation were long term.

All of the above would result in less treatment of the waste and poorer quality effluent being discharged into receiving waters raising the likelihood of fish kills, and other environmental damage. Of most concern, of course, would be the public health problem associated with transmission of disease through drinking water intakes further downstream in the same body of water.

MANUAL FOR EMERGENCY PROCEDURES DURING CR

To deal with the above potential problems during CR, a manual has been prepared entitled "Manual for Emergency Sewage Procedures During Crisis Relocation", August 1978 (Part II of this report). This manual is designed with two objectives in mind: 1) to provide a set of guidelines with which a host area sewage treatment facility engineer/operator can estimate the impact and determine how to cope with the added load caused by an increased population associated with CR; and 2) to provide DCPA personnel with an approach for predicting how their CR plans will impact sewage treatment plant operations and how and when sewage treatment plant capacities may be a factor limiting the maximum number of relocatees that a particular host area can support.

REPORT OBJECTIVES

This technical report is designed to supplement the above-mentioned manual and to be used solely in conjunction with it. The report has three primary objectives:

1. To provide background material, references, etc. on the rationale behind the equations used in the manual worksheets and the recommendations and actions suggested in the manual.
2. To discuss the "field testing" phase of the manual and report on the observations and conclusions drawn from such testing.
3. To discuss certain topics considered relevant to the overall subject of the manual and report but not considered appropriate for inclusion in the manual.

REPORT ORGANIZATION AND AUDIENCES

Section 2 of this report provides background information on the development of the manual. This section may be of interest to Defense Civil Preparedness Agency and State Civil Defense personnel and sewage treatment plant operators.

Section 3 discusses the testing of the manual and includes a discussion of the treatment plants visited, both in California and Colorado, and presentation of some generalized findings concerning potential problems with treatment plants during CR based on this testing phase. This section may be of interest to Defense Civil Preparedness Agency and State Civil Defense personnel and sewage treatment plant operators.

Section 4 of this report discusses two issues not covered in the manual: 1) environmental impact evaluation of CR sewage treatment plant operations, and 2) pre-CR construction modifications which would allow for increased capacity during an emergency CR situation. This section may be of interest to EPA; public health personnel and local engineering departments planning future facilities or expansion of present facilities.

Section 2
MANUAL DEVELOPMENT

METHODOLOGY

Review of Environmental Protection Agency data (Ref. 4) inventorying sewage treatment facilities in the United States indicates that the sewage treatment facilities in small towns can be categorized as primary treatment, trickling filters, ponds, aerated lagoons, and activated sludge. Thus, this report and the associated manual deal with these types of treatment facilities. Each of the above types of treatment plants can be broken down into a series of treatment systems such as primary sedimentation, biological treatment, digestion, solids handling, etc.

To ensure optimum operation during CR, it is important for the treatment plant operator to be able to anticipate problems within each of the various systems. This will help determine priorities in terms of system monitoring and operational modifications. To aid the plant operator in this task, worksheets are included in the manual to detail each individual calculation that is needed to estimate performance of the different systems, and to identify trouble areas within the plant. The manual worksheets are arranged to provide a step-by-step analysis of present operating conditions, the projected operational loadings during CR, and the effect of these increased loadings on system operations. Each individual calculation and its answer are indexed by a number and letter which allows easy cross-reference to related calculations and sections within the manual.

The method used to quantify the effects of CR on wastewater treatment plant performance was to take existing empirical data on the effects of loading on efficiency for the various plant operations. These data were

generalized and simplified, usually by a linear curve representative of the data. For some systems empirical equations and generalized design curves, such as the National Research Council equation for trickling filters (Ref. 5), have been developed to predict the effect of loading on removal efficiency. The actual performance of the designed system, however, may vary from these generalized curves because of the peculiarities of a particular waste or equipment configuration. Even though these generalized descriptions cannot predict the exact level of treatment, they do describe the effects of changes in loading on treatment efficiency. The approach used to predict the effects of CR on the various treatment systems was to utilize the ability of these generalized descriptions to predict the change in treatment due to changes in loading, rather than to predict the exact level of treatment. This was done by assuming that the rate of change in treatment efficiency as a function of the loading given by the linear approximation developed for each system can be used to describe the effect of crisis relocation. Specifically, the change in loading multiplied by the slope of the linear approximation yields the change in treatment efficiency.

Each plant, when designed, is given a nominal capacity which in most cases is different from its effective capacity during CR. Thus, physical size is used to estimate the actual effective capacity of each treatment system with respect to the organics, solids, and hydraulic loading. Actual tank dimensions are used to generate the volume, surface area, weir lengths, etc. Each of these treatment systems have finite capacities so that if the increase in waste generation due to CR is large enough, the capacity of any of them can be exceeded. Because each treatment plant consists of an interdependent combination of unit processes, the description of likely deficiencies will therefore require analysis of each plant as a whole.

The per capita waste production of relocated population is divided into three components: solids, organic or BOD, and hydraulic flow. Increases in all of these components are expected during CR, however, each of the treatment systems would not be expected to have problems with all three. That is, the response of each system would be relatively insensitive to one or more of these increases. Table I-1 identifies the critical

Table I-1

Identification of the Critical Waste Contributions for the Major Components of Various Waste Treatment Systems

System	Hydraulic Flow	Waste Contribution Organic BOD	Suspended Solids
Primary			
Primary Clarifier	X	--	--
Digesters	--	X*	X
Trickling Filters			
Filter	X	X	--
Secondary Clarifier	X	--	--
Ponds	--	X	--
Aerated Lagoons	--	X	--
Activated Sludge			
Aeration Tank	--	X	--
Secondary Clarifier	X	X	--
Individual Systems			
Septic Tank	--	--	X
Disposal System	X	--	--

X denotes major impact expected.
* when combined with secondary treatment.

waste contributions for the major components of each of the treatment systems. While the non-indicated waste contributions will have some effect on the treatment systems, the contributions identified as critical in Table I-1 can be expected to be the major cause of decreased treatment. The manual provides worksheets which allow the qualitative data in Table I-1 to be evaluated as follows: First, to eliminate the decrease in treatment as a function of waste increase and second, to identify whether a major decrease in treatment (i.e., failure) occurs.

PER CAPITA SEWAGE LOAD CONTRIBUTIONS

The first task in assessing the impact of CR on sewage treatment plants is to develop the probable per capita contributions of BOD, solids, and hydraulic flow that will be added by the relocated population. This was done by reviewing published values for waste production under various conditions and then developing probable contributions.

Unfortunately, most summary values on per capita loadings for combined sewer systems represent average conditions and not the purely domestic contributions expected during CR. The increases in sewage load during CR will be assumed to be totally domestic in nature. (This is because industry would not be moved during the crisis, only the domestic population.) Table I-2 presents a summary of the findings of numerous studies on residential water use.

A study by Watson et al. (Ref. 6) shows similar levels of domestic water consumption affecting the flow to the treatment facility. The study consisted of monitoring three homes from different income levels and the per capita daily flow and market value of these homes is presented in Table I-3.

Table I-2

Interior Residential Water Usage Comparison as a Percentage of Average Daily Use

Reference	Reference No.	Category of Use: Toilet Flushing	Bathing	Laundry	Dishwashing	Drinking and Cooking	Miscellaneous	Total Flow gpcd
McPherson (1976)	1	42	27	← 17 →		8	6	
California DWR (1976)	2	42	32	14	← 12 →			
ERCO (1975)	3	39	34	14	6	5	2	64
Laak (1975)	4	47*	21*	18*	← 9* →			41*
Murawczyk and Ihrig (1973)	5							62
Ligman (1972)	6	41*	26*	19*	← 10* →			45*
Wallman (1972)	7	27-45*	18-36*	18*	← 13* →			30-50*
Howe, et al (1971)	8	45	30	← 20 →		5		
Bailey and Wallman (1971)	9	39	34	14	← 11 →		2	64
USGS (1962)	12	41	37	4	← 11 →		7	
Haney and Hamann (1965)	13	39	32	14	← 11 →		4	61.5
Bennett (1975)	14	33*	24*	27*	← 16 →			44.5*
Siegrist, Witt and Boyle (1976)	15	22*	23*	25*	← 11* →		19*	
Water Encyclopedia (1970)	16	42	38	7	← 11 →		2	
Bostian: EPA (1973)	17	27-45	22-36	18	← 13 →		2	
US PHS (1967)	18	30	35	20	← 15 →			
Chanlett (1973)	19	43	38	7	← 11 →		11	
Univ. of Wisc. (1973)	24	40	30	15	← 10 →		5	50
Bailey, et al (1969)	25	49*	32*	4*	← 12* →		3*	
AVERAGE		40	30	15	6	5	4	60

*Rural figures.

Source: Weston Environmental Consultants-Designers, 1978.(Ref. 7)

Table I-3

Comparison of Market Value with Flow in GPD

	Home		
	1	2	3
Market Value	$45,000	$25,000	$18,000
Flow gpd/capita	65	45	25

The average flow is 45 gpd/capita for these three test homes.

Another study by Zanoni in 1972 (Ref. 8) indicates per capita contributions with a flow value of 58 gpd per capita. This study was totally residential with a population of 1,207: 613 adults and 594 children. The survey ran from November 1969 to May 1970. The maximum flow was 80 gpd per capita and the minimum was 41 gpd per capita. Based upon these data, it is estimated that the daily sewage flow will be 50 gallons per relocatee: 3 for drinking and cooking, 20 for bathing, 3 for oral hygiene, and 24 for toilet flushing.

Existing sewage flows and designed treatment capacity for various towns are presented in Table I-4. One of these (Canon City, Colorado) has been selected as a potential relocation site and can serve as an example of the magnitude of the problem during CR. The current population of 11,000 produces 2.036 mgd of sewage (185 gal per capita per day) and during relocation there will be an expected 36,709 relocatees as projected by DCPA in January 1976 (Ref. 9). Assuming 50 gal per capita per day, this represents and additional 1.835 mgd of flow or an approximate doubling of the flow to the plant while experiencing an approximate four-fold increase in population.

Besides the hydraulic flow, the major effects of the relocated population on sewage treatment will be the increases in suspended solids and in BOD. The literature was surveyed to estimate the daily per capita suspended

Table I-4

Existing Flow (1974 Data)

State	Town	Population	Flow (G/pc/d)	Designed (MGD)	Actual (MGD)
Pennsylvania	Beaver Falls	22,600	68	3.30	1.54
	Danville	11,900	134	3.22	1.60
New York	Webster	10,000	80	2.5	0.8
	Saratoga Springs	18,600	188	3.5	3.5
	Buffalo*	640,000	278	150.0	178.0
Arizona	Casa Grande	11,000	49	3.0	0.6
	Flagstaff	30,000	56	3.0	1.7
	Phoenix*	460,000	80	45.0	36.8
Illinois	Woodridge	17,000	135	2.0	2.3
	Rock Falls	10,200	115	2.5	1.18
Iowa	Keokuk	14,530	181	5.0	2.63
Colorado	Canon City**	11,000	185	2.12	2.036

*Large cities for comparison.
**(36,709 relocatees)

Source: Environmental Protection Agency, 1974. (Ref. 4)

solids and BOD contributions of the relocated population. As with flow, the estimates of the daily contributions per relocated person are based upon the literature values for purely domestic contributions. These literature data are summarized in Tables I-5 and I-6 and from these data, the estimated daily suspended solids and BOD contributions per relocated person are estimated to be .08 pounds of suspended solids and .1 pounds of BOD (5 day, 20^{o}C). Combining these per capita contributions with the number of relocatees will provide the added load on the existing facilities due to CR.

Using Canon City, Colorado, again as an example, the plant is a trickling filter plant with an existing flow of 2.036 mgd and an influent BOD of 150 mg/ℓ or 2,547 pounds per day. The relocation of 36,709 persons to Canon City would increase the BOD load on the plant by an estimated 3,671 pounds a day, an increase in the BOD load of approximately 2.5 times. Again, this demonstrates that CR will place large demands upon the existing sewage treatment facilities.

Before the effect of this large demand on a particular treatment facility can be evaluated, it is necessary to look at the designed capacity. For example, sewage treatment plants are designed to take into account diurnal and seasonal variations as well as the future growth of the plant. Fig. I-1 shows a typical diurnal flow variation affecting plant function. Flow consists of the household water which is used and discharged to the sewer showing a diurnal flow pattern with given variations in sewage flow rates upon reaching the sewage plant: (1) low flows being in the early morning hours when the base flow consists of leakage, infiltration, and low volumes of sanitary waste; (2) peak flows arrive at the plant by the late morning from early morning water consumption; often a second peak flow will occur in the early evening. Fig. I-2 gives us an example of seasonal changes. An obvious increase is shown in wet weather flows due to infiltration and illegal household connections to gutters. There is even a more drastic flow change for a combined sewer system (storm drains as well as sewer lines).

Table I-5

Watson (1967) Three Homes Study*

	Home 1	Home 2	Home 3
Flow gpd/capita	65	45	25
SS lb/capita/day	.19	.09	.09
BOD (5 day, 20°C) lb/capita/day	.26	.14	.10

* Ref. 6.

Table I-6

1967-1970 Study By Zanoni (1972) Population 1,207 (Domestic Waste)*

	Maximum	Minimum	Average
Flow gpd/capita	80	41	57.6
SS lb/capita/day	.1363	.0707	.0973
BOD lb/capita/day	.1145	.0453	.0837

* Ref. 8.

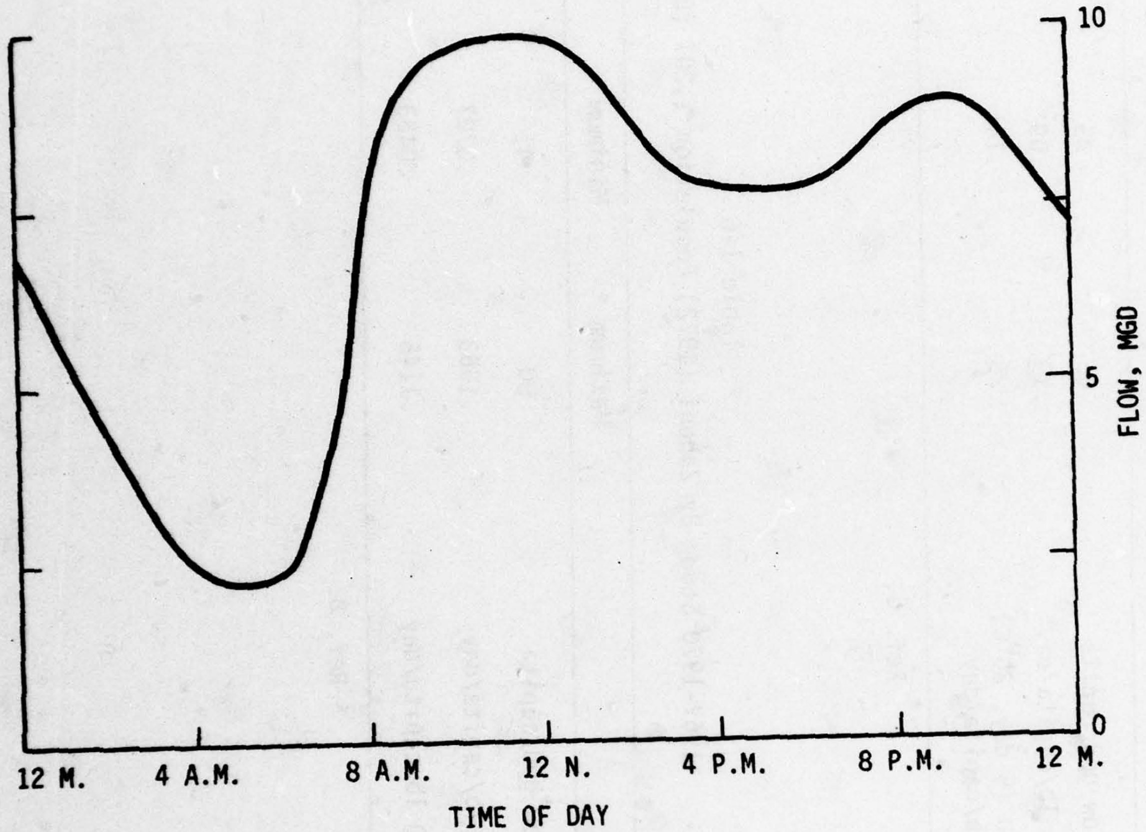

Fig. I-1. Typical Hourly Variation in Flow.
Source: Metcalf and Eddy (1972). (Ref. 10)

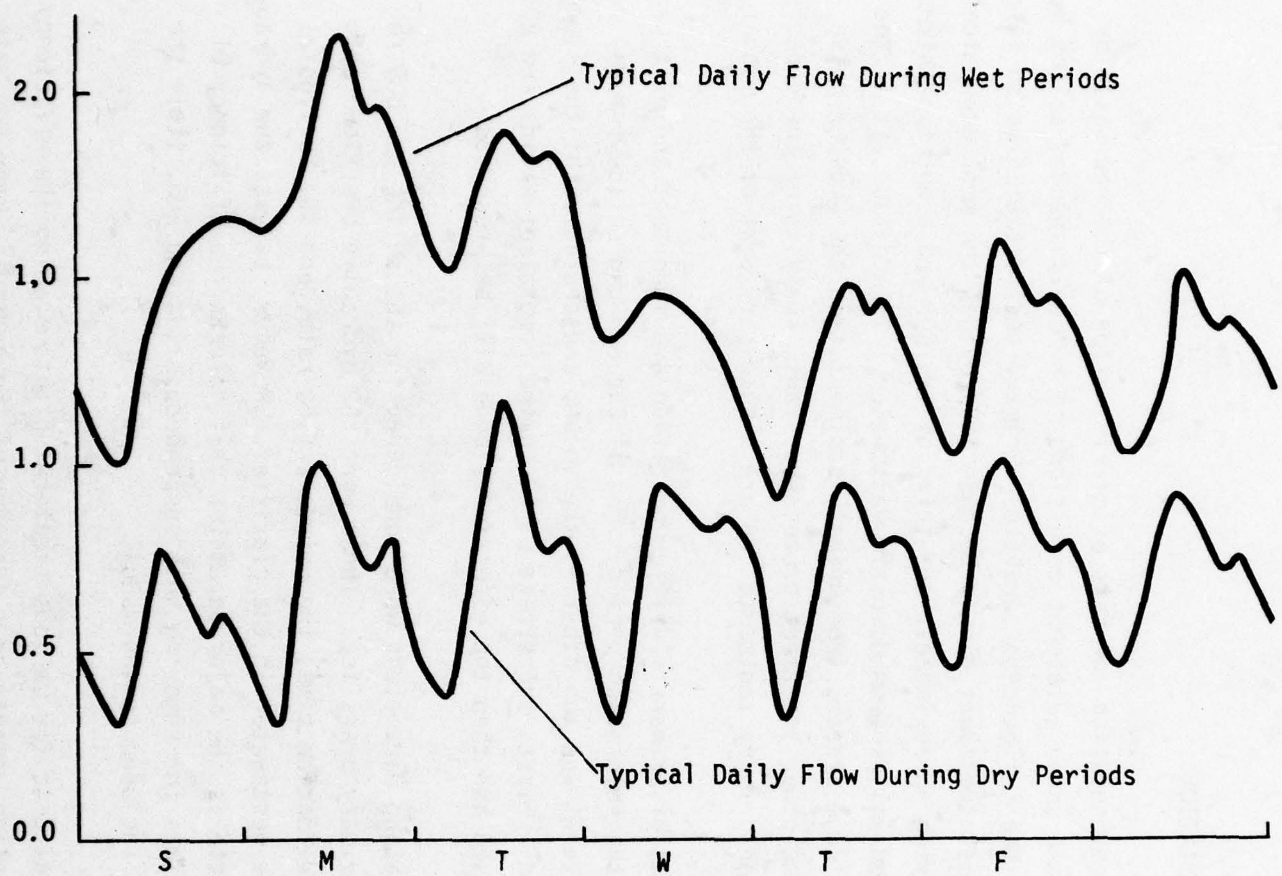

Fig. I-2. Typical Daily, Weekly, and Seasonal Variations in Sewage Flow.
Source: Metcalf and Eddy (1972).(Ref. 10)

PRIMARY SEDIMENTATION

Primary sedimentation consists of clarification of the raw waste by holding the waste under quiescent conditions to remove suspended solids by settling under the influence of gravity. Primary sedimentation is an integral part of most treatment plants because it provides the most economical method of removing approximately one-third of the BOD and about two-thirds of the suspended solids from domestic wastewater. In addition, it is the effluent and sludge streams from primary sedimentation that must receive treatment by the other treatment processes. Thus, analysis of the expected effects of CR on primary sedimentation are a necessary part of the manual.

Two aspects of primary clarifier operation are important and must be predicted for the relocation period. One is the BOD and solids removal from the liquid effluent and the other is the volume and character of the sludge solids produced. First, the effect of CR on the removal of solids and BOD will be discussed and then the effect on sludge will be presented.

Four operating parameters were considered for the solids and BOD removal by the primary clarifier. These were the hydraulic overflow rate, the hydraulic detention time, the weir overflow rate, and the horizontal velocity of the wastewater in the clarifier. However, because the hydraulic overflow rate is the major parameter that governs the efficiency of primary clarifiers for removing both suspended solids and BOD, it is the only parameter included in the manual.

Operational data for various treatment plants showing the efficiency of suspended solids removal as a function of the hydraulic overflow rate are presented in Fig. I-3. Both of these curves are nearly linear over the typical design range so that a linear approximation, also shown in Fig. I-3, is used to estimate the effects of CR on suspended solids removal in the primary clarifier. The slope of this approximation indicates

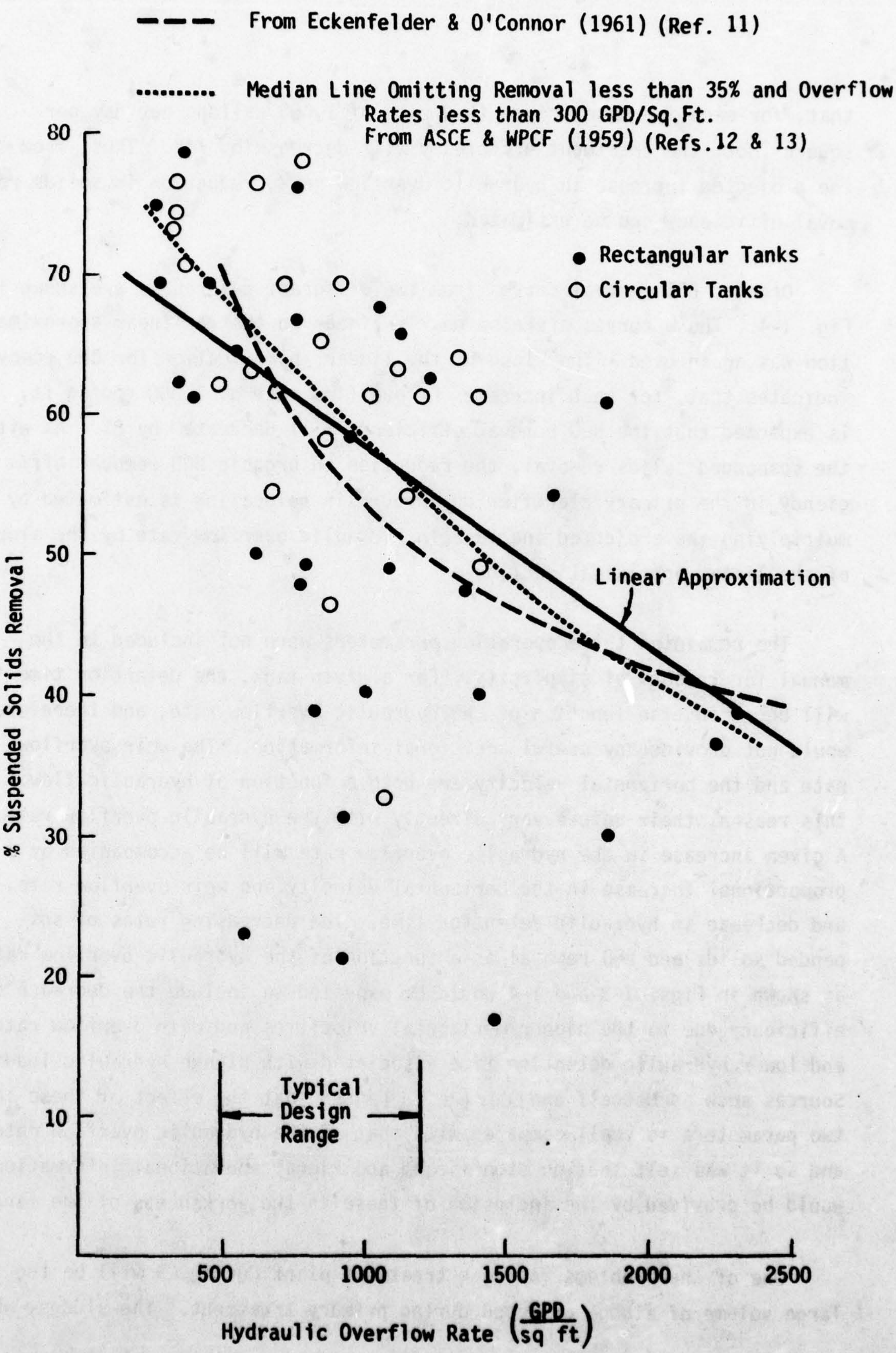

Fig. I-3. Suspended Solids Removal as a Function of Hydraulic Overflow Rate

that, for each increase in overflow rate of 1,000 gallons per day per square foot, the treatment efficiency will decrease by 14%. Thus, from the projected increase in hydraulic overflow rate, reduction in solids removal efficiency can be estimated.

Organic BOD removal curves from two different references are shown in Fig. I-4. These curves are also nearly linear so that a linear approximation was again used. The slope of the linear approximation for BOD removal indicates that, for each increase in overflow rate of 1,000 gpd/sq ft, it is expected that the BOD removal efficiency will decrease by 8%. As with the suspended solids removal, the reduction in organic BOD removal efficiency in the primary clarifier during crisis relocation is estimated by multiplying the projected increase in hydraulic overflow rate by the slope of the linear approximation line.

The remaining three operating parameters were not included in the manual for reasons of simplicity. For a given tank, the detention time will be an inverse function of the hydraulic overflow rate, and therefore would not provide any useful additional information. The weir overflow rate and the horizontal velocity are both a function of hydraulic flow. For this reason, their values vary directly with the hydraulic overflow rate. A given increase in the hydraulic overflow rate will be accompanied by a proportional increase in the horizontal velocity and weir overflow rate, and decrease in hydraulic detention time. The decreasing rates of suspended solids and BOD removal as a function of the hydraulic overflow rate as shown in Figs. I-3 and I-4 would be expected to include the decrease in efficiency due to the higher horizontal velocities and weir overflow rates and lower hydraulic detention time associated with higher hydraulic loading. Sources such as Metcalf and Eddy (Ref. 10) agree that the effect of these last two parameters is small compared with that of the hydraulic overflow rate, and so it was felt that no significant additional operational information would be provided by the inclusion of these in the worksheets of the manual.

One of the problems facing a treatment plant during CR will be the large volume of sludge produced during primary treatment. The sludge, which

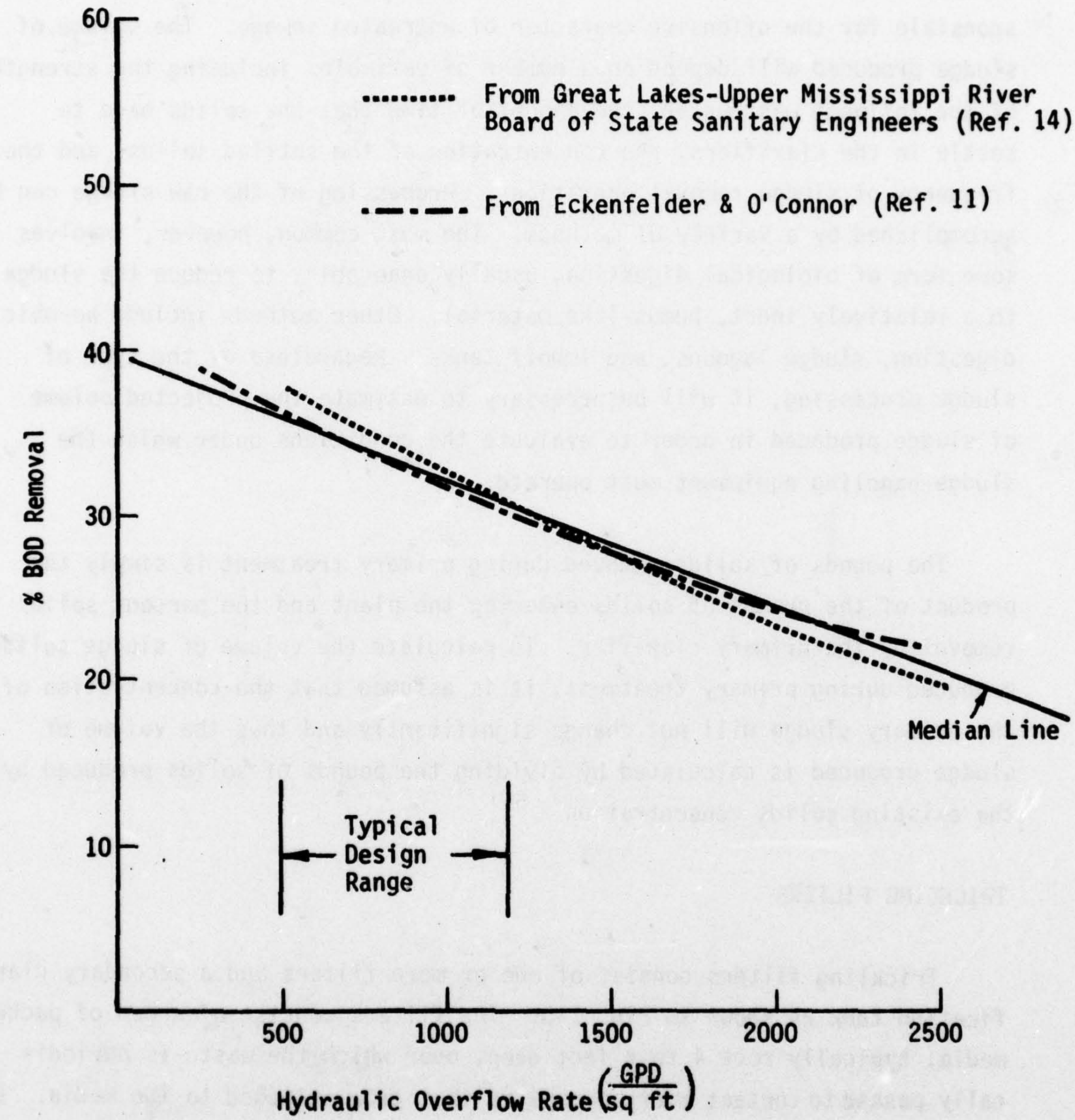

Fig. I-4. **BOD Removal as a Function of Hydraulic Overflow Rate**

is typically 5% to 10% solids, consists largely of the organic matter responsible for the offensive character of untreated sewage. The volume of sludge produced will depend on a number of variables including the strength of the influent wastewater, the amount of time that the solids have to settle in the clarifiers, the concentration of the settled solids, and the frequency of sludge removal operations. Processing of the raw sludge can be accomplished by a variety of methods. The most common, however, involves some form of biological digestion, usually anaerobic, to reduce the sludge to a relatively inert, humus-like material. Other methods include aerobic digestion, sludge lagoons, and Imhoff tanks. Regardless of the type of sludge processing, it will be necessary to estimate the projected volume of sludge produced in order to evaluate the conditions under which the sludge-handling equipment must operate.

The pounds of solids removed during primary treatment is simply the product of the pounds of solids entering the plant and the percent solids removal by the primary clarifier. To calculate the volume of sludge solids produced during primary treatment, it is assumed that the concentration of the primary sludge will not change significantly and thus the volume of sludge produced is calculated by dividing the pounds of solids produced by the existing solids concentration.

TRICKLING FILTERS

Trickling filters consist of one or more filters and a secondary clarification tank as shown in Fig. I-5. The filters consist of a bed of packed media, typically rock 4 to 6 feet deep, over which the waste is periodically passed to contact micro-organisms that grow attached to the media. BOD is removed from the waste by oxidation to carbon dioxide and synthesis to produce new microbial mass. Excessive accumulation of micro-organisms is prevented by sloughing of micro-organisms from the filter media. The sloughed micro-organisms are then removed from the plant effluent by settling under the influence of gravity in the secondary clarifier.

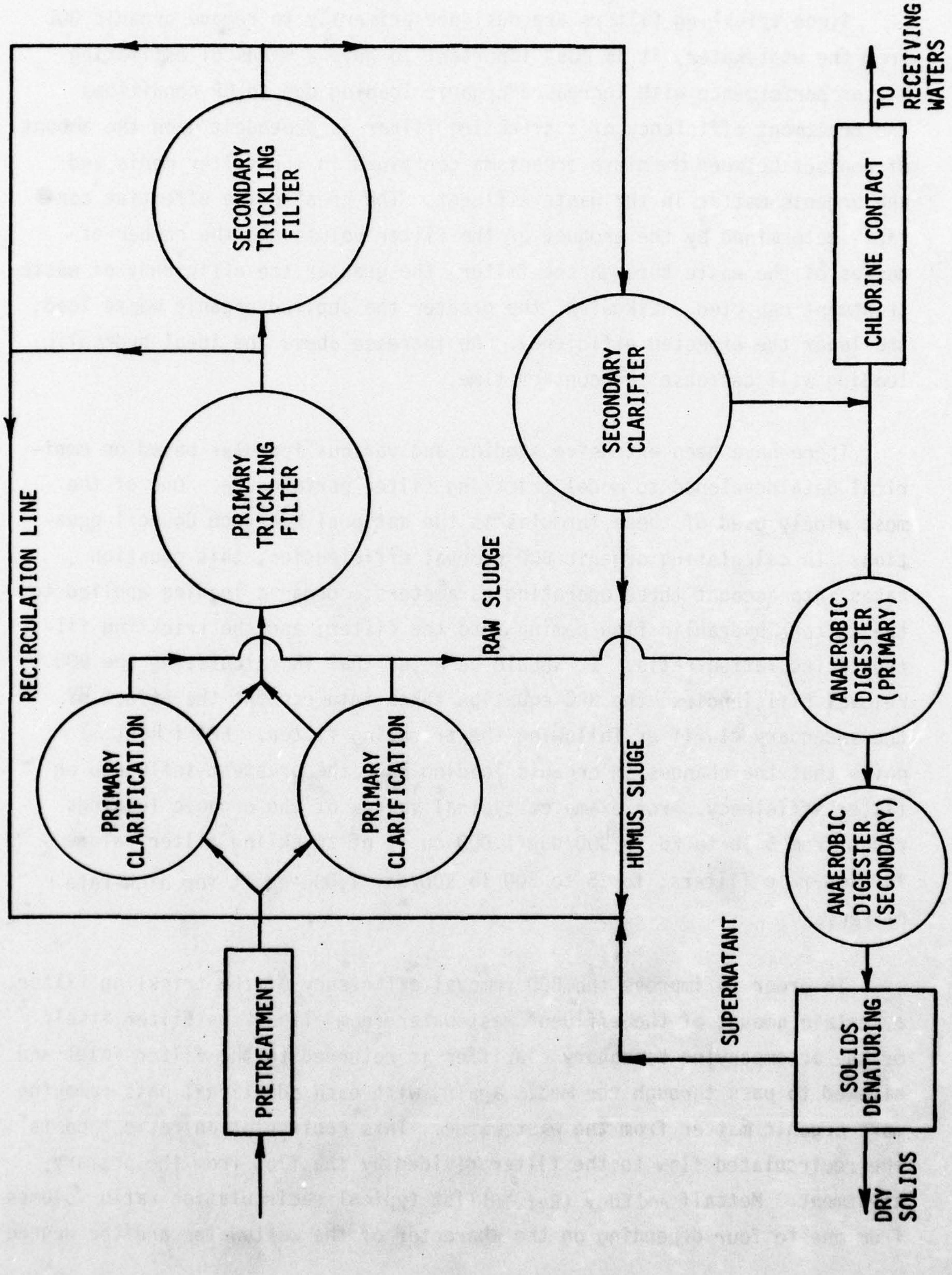

Fig. I-5. Typical Trickling Filter Plant.

Since trickling filters are designed primarily to remove organic BOD from the wastewater, it is most important to have a means of estimating filter performance with increased organic loading due to CR conditions. The treatment efficiency of a trickling filter is dependent upon the amount of contact between the micro-organisms contained in the filter media and the organic matter in the waste effluent. The greater the effective contact, determined by the product of the filter volume and the number of passes of the waste through the filter, the greater the efficiency of waste treatment expected. Likewise, the greater the applied organic waste load, the lower the expected efficiency. An increase above the ideal hydraulic loading will decrease the contact time.

There have been extensive studies and various formulas based on empirical data developed to model trickling filter performance. One of the most widely used of these formulas is the National Research Council equation. In calculating organic BOD removal efficiencies, this equation takes into account three operating parameters: organic loading applied to the filter; hydraulic flow coming into the filter; and the trickling filter recirculation ratio. It should be noted that in calculating the BOD removal efficiencies, the NRC equation takes into account the effect of the secondary clarifier following the trickling filter. EPA (Ref. 5) notes that the changes in organic loading have the greatest influence on filter efficiency. For example, typical values of the organic loadings range from 5 lb to 25 lb BOD/day/1,000 cu ft of trickling filter volume for low-rate filters, to 25 to 300 lb BOD/day/1,000 cu ft for high-rate filters.

In order to improve the BOD removal efficiency of the trickling filter, a certain amount of the effluent wastewater from either the filter itself or the accompanying secondary clarifier is returned to the filter inlet and allowed to pass through the media again, with each additional pass removing more organic matter from the wastewater. This recirculation ratio then is the recirculated flow to the filter divided by the flow from the primary treatment. Metcalf and Eddy (Ref.10) list typical recirculation ratio volumes from one to four depending on the character of the wastewater and the degree

of treatment. Quite often in actual plant operations, this ratio will vary throughout the day depending on influent flow conditions.

Because of the wide range of performance of trickling filters due to individual design and flow characteristics, a study was conducted to estimate the effect of CR on organic BOD removal efficiencies. The NRC equation was solved assuming that the total hydraulic flow to the filter was fixed at the value before relocation. Thus, as the hydraulic flow from primary treatment increased, the recirculated flow was reduced in order to keep the total flow constant. Also the organic BOD loading to the filter increased proportionately with the hydraulic flow increase based on the daily per capita contributions of 0.10 pounds BOD and 50 gallons. Using the initial BOD concentrations of 150,240 and 500 mg/ℓ; initial BOD loadings of 25, 50, and 100; and initial recirculation ratios of 1, 2, 3, and 4, the NRC equation was used to determine the effect on trickling filter efficiency. These data are shown in Fig. I-6. These values represent the range of typical BOD loadings and recirculation ratio reported in the literature and BOD concentrations greater than, the same as, and less than would occur during CR. The data in Fig. I-6 show that treatment improves with higher recirculation ratios and decreases with increased BOD concentrations. Fig. I-7 provides observed values of trickling filter performance, and a typical curve generated from the NRC equation. Also shown is the range of values of the solutions to the NRC equation, shown previously in Fig. I-6. It was felt that these concentrations represent a typical range of concentrations that could be expected for municipal wastewater during CR. Unlike the primary clarifier, the curves cannot be approximated by a single straight line. However, a reasonably good fit can be obtained with three straight lines, also represented on Fig. I-7 as the linear approximation. The three segments of this line have different slopes which correspond to the approximate changes in BOD loading on the filter. The greatest decrease in efficiency would be expected in the range of up to 40 lbs BOD/1,000 cu ft/day. The slope in this region indicates a decrease in efficiency of 7.5% per 10 lb BOD/1,000 cu ft/day. For loadings between 40 lb and 150 lb BOD/1,000 cu ft/day, the decline in treatment is more gradual and is represented by a slope indicating a decrease of 1.7% per

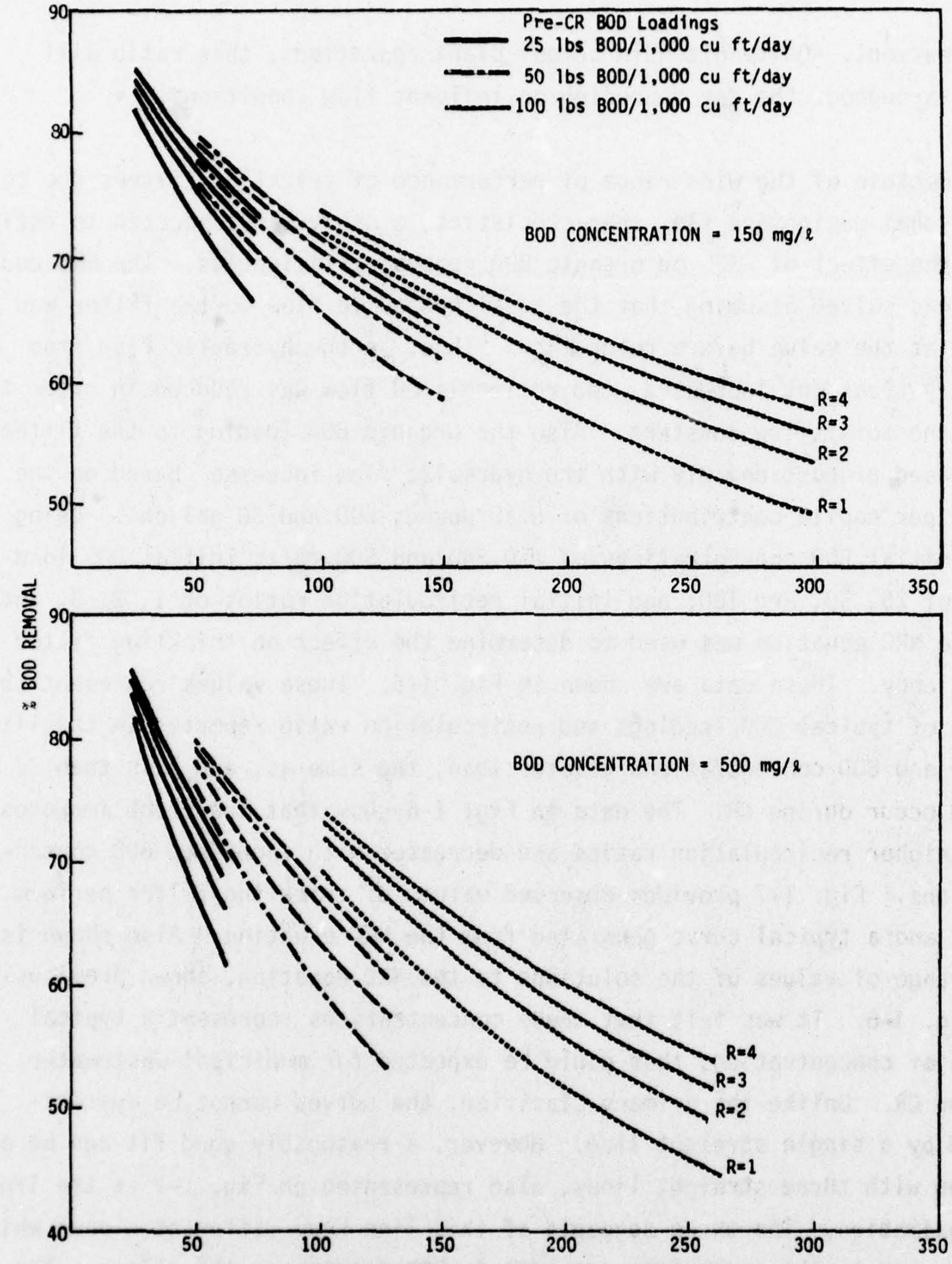

Fig. I-6. Solutions to NRC Equation Assuming Constant Flow to Trickling Filter and Varying BOD Concentrations and Recirculation Ratios.

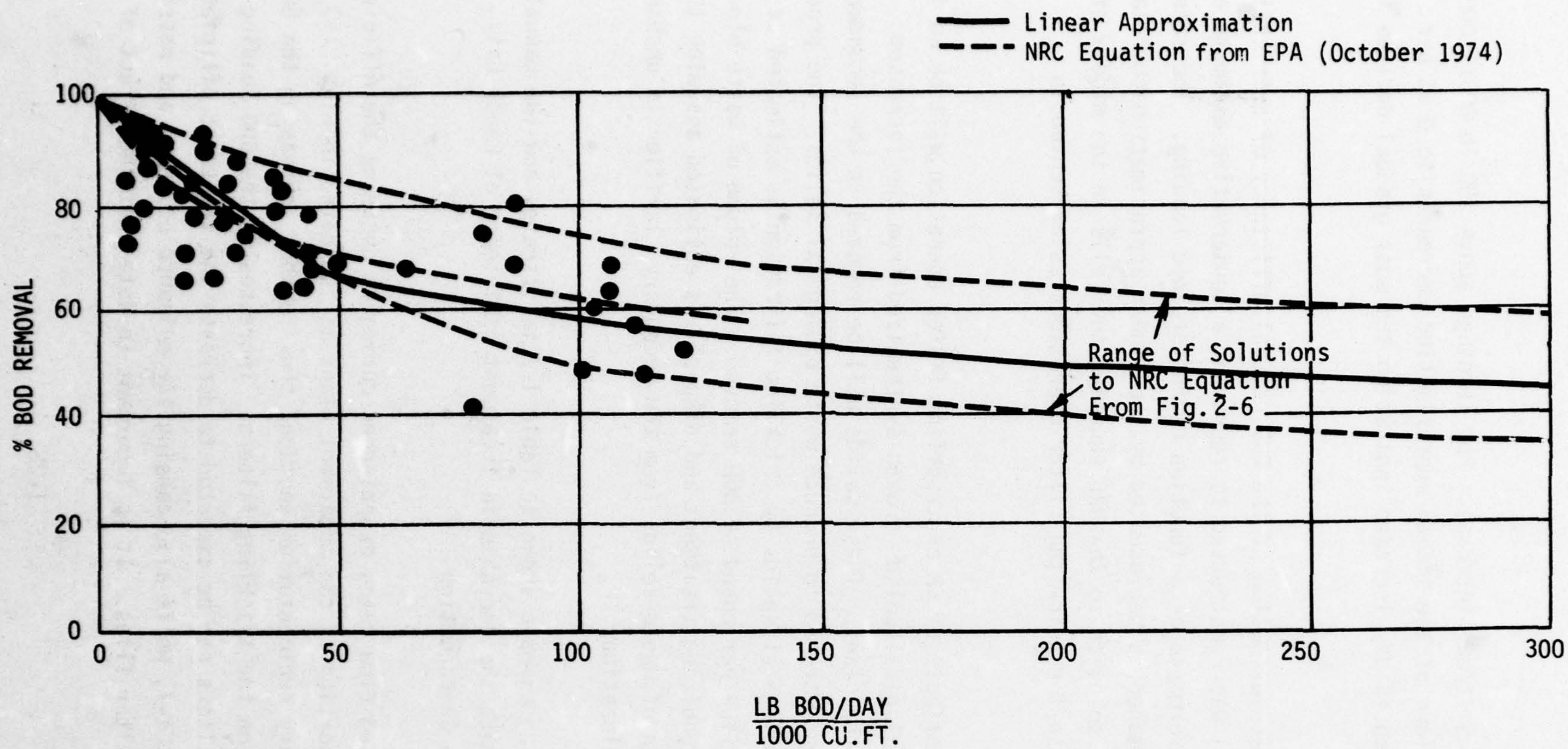

Fig. I-7. Comparison of Trickling Filter Operating Data* with NRC Equation and the Linear Approximation.
* From EPA Process Design Manual for Upgrading Existing Wastewater Treatment Plants. (Ref. 5)

10 lb BOD/1,000 cu ft/day increase. For loadings above 150 lb BOD/1,000 cu ft/day, the slope of the linear approximation decreases to 0.5% per 10 lb BOD/1,000 cu ft day increase indicating the most gradual decline in treatment.

The linear approximation of the BOD removal efficiency of a trickling filter (Fig. I-7) was constructed to represent a conservative estimate of the filter's performance as a function of the organic loading. The rate of change of performance as represented by the linear approximation correlates closely with the solution to the NRC equation and falls in the middle of the empirical data for trickling filter operations as presented in Fig. I-7.

One of the effects of CR on trickling filter operation will be an increase in the biological solids growth synthesized from the increased organic load on the plant. These solids will be removed in the secondary clarifier and concentrated to produce waste biological solids. The production of waste biological solids by trickling filtration is estimated at 0.5 pounds of solids per pound of BOD removed. The volume of waste biological solids requiring treatment and disposal is estimated assuming that the concentration of waste solids from the secondary clarifier is unchanged during crisis relocation.

The following example shown in Table I-7 illustrates how the manual can be used to estimate the decrease in treatment efficiency at Canon City, Colorado, due to CR conditions.

The increased flow rates experienced during CR decrease the efficiencies of the primary portion of the treatment plant as indicated in Figs. I-3 and I-4 in the primary sedimentation section, thus further increasing the BOD and solids load on the trickling filters. Increases in the BOD loading on the trickling filters can be expected to decrease the treatment efficiency as shown in Fig. I-7, while also causing the nuisance of odors and possibly the growth of filter flies. It is important to note that the effect of

Table I-7
Estimated Effect of Crisis Relocation at Canon City, Colorado

Parameters	Before	After
Population	11,000	47,709
Flow (mgd)	2.036	3.871
Influent		
BOD lb/day)	2,547	6,218
(mg/ℓ)	150	192
Primary Effluent*		
BOD (mgd)	130	144
lb/day	1,749	4,663
Trickling Filter Effect**		
BOD mg/ℓ	21	36
lb/day	357	1,166

*Assumed 2,000 ft^2 clarifier.
**Assumed 130,000 ft^3 media.

increases in the amount of waste produced during CR cause only a gradual reduction in treatment. Therefore, such a system would be expected to handle the increases due to relocation and still provide substantial treatment. It is also important to note the interrelationship between the primary and trickling filter portions of the plant—specifically, that an increase in hydraulic flow decreases the BOD removal of the primary portion of the plant, which in turn increases the BOD load on the trickling filters reducing their efficiency.

Referring to Table I-7, the treatment plant in Canon City, Colorado was assumed to have 2,000 square feet of primary clarifier area, and 130,000 cubic feet of trickling filter media. Using Figs. I-4 and I-7, the assumed plant size and the per capita contributions of flow and BOD, the effect of the projected relocated population on the plant effluent was calculated. The expected effect of CR for this example is an approximate doubling of the effluent BOD concentration and four-fold increase in pounds of BOD. If this projected increase in BOD is unacceptable, then the various corrective actions need to be implemented.

ACTIVATED SLUDGE

Process Description

Activated sludge is a treatment process which involves mixing and aerating wastewater and biological sludge (micro-organisms) together and then separating the biological solids and returning a portion to the aeration process as needed. Activated sludge systems contain two major components; the aeration tank or biological reactor, and the secondary clarifier or solids separator. In the aeration tank, the influent wastewater is mixed with return activated sludge from the secondary clarifier. The return sludge has a high concentration of micro-organisms which utilize the organic waste (BOD) as food. Air is introduced into the aeration tank to provide oxygen for the micro-organisms. The BOD in the wastewater is removed by the micro-organisms by two mechanisms: oxidation of the waste to carbon dioxide gas; and synthesis of new microbial mass. The mixture of wastewater and micro-organisms, called mixed liquor, is pumped to the

secondary clarifier where the biological solids are allowed to settle. Part of this settled sludge is returned to mix with the influent wastewater to control the mixed liquor suspended solids (MLSS) concentration in the aeration tank. The excess sludge, called waste activated sludge, is pumped to the digester or other sludge stabilization process, thus removing a portion of the solids from the activated sludge system.

Although the manual concentrates primarily on the conventional activated sludge process, there are numerous variations to the process, the most common of which are the following:

1. Step Aeration where the influent wastewater is introduced at several points along the aeration tank.
2. Complete Mix where influent wastewater and returned sludge are introduced uniformly throughout the aeration tank.
3. Contact Stabilization where influent wastewater is initially mixed with activated sludge; then the settled sludge is moved to a stabilization tank where the microbes are then allowed to break down the absorbed organics.
4. Extended Aeration which is essentially the same as the complete mix and is utilized by many small plants. These small plants usually have no primary treatment and aerate the raw wastewater for 24 hours rather than the 6 to 8 hours in conventional plants.

Table I-8 provides typical comparative design parameters for each of these activated sludge processes.

To analyze the operation of an activated sludge system under CR conditions, many operating parameters for both the aeration tank and the secondary clarifier must be considered and the interrelationships among these parameters is rather complex. For this reason, the aeration tank and secondary clarifier are analyzed separately. The key to successful operation of the activated sludge process is the efficiency of the secondary

Table I-8

Typical Activated Sludge Design Parameters

Process Modification	Flow Regime	Sludge Retention Time (Days)	Food to Microorganism Ratio-#BOD_5/ MLVSS/day	Aerator Loading #BOD_5/ 1,000 ft^3 Tank Volume	Mixed Liquor Suspended Solids (mg/ℓ)	Detention Time (hr)	Recirculation Ratio
Conventional	Plug	5 - 15	0.2 - 0.4	20 - 40	1,500 - 3,000	4 - 8	0.25 - 0.5
Complete Mix	Complete Mix	5 - 15	0.2 - 0.6	50 - 120	3,000 - 6,000	3 - 5	0.25 - 1.0
Step Aeration	Plug	5 - 15	0.2 - 0.4	40 - 60	2,000 - 3,500	3 - 5	0.25 - 0.75
Contact Stabilization	Plug	5 - 15	0.2 - 0.6	30 - 75	1,000 - 4,000* 4,000 - 10,000**	0.5-1.5*	0.5 - 1.5
Extended Aeration	Complete Mix	20 - 30	0.05- 0.15	10 - 15	2,000 - 6,000	24	0.5 - 2.0
Pure Oxygen Systems	Complete Mix Reactors in Series	8 - 20	0.25- 1.0	100 - 250	4,000 - 8,000	2 - 5	0.25- 0.5

*Contact unit
**Stabilization tank

Source: Environmental Protection Agency (Ref. 15).

clarifier for it is here that the biological solids which represent a large portion of the influent BOD are removed from the process influent. For this reason, the secondary clarifier will be used as a starting point for analyzing the system operation.

Secondary Clarifier

The secondary clarifier has two functions: separation of the activated sludge solids from the mixed liquor producing a clear effluent, and concentration of the settled solids for return to the aeration tank and for solids wasting. Each of these functions uses a separate operating parameter to define the operational limits of the clarifier: hydraulic overflow rate for solids separation, and solids loading rate for solids concentration.

The hydraulic loading, expressed as the hydraulic overflow rate in gallons per day per square foot of clarifier surface area, is directly related to the clarifier's ability to effectively remove solids from the effluent. The overflow rate, based on peak hourly plant flow, should typically not exceed 1,200 gpd/sq ft because higher overflow rates will increase the amount of solids being carried over the weir usually by causing the entire sludge blanket to rise from the bottom of the clarifier. This loss of solids will result in a decrease in the solids within the system and can lead to process failure.

As with the primary clarifier, the plant operator can estimate the overflow rates based on projected average and peak plant flow. If the overflow rate based on the projected average plant flow exceeds 1,200 gpd/sq ft, the process will fail and the situation can be dealt with only by reducing the flow to the activated sludge system. This can be accomplished either by the reduction of the flow into the plant by community water conservation, or by diverting some of the flow elsewhere. If flow cannot be reduced, severe degradation of effluent quality will be inevitable. If, however, a hydraulic overload does not occur at the average flow, community flow equalization should be considered to

maintain a nearly constant acceptable flow into the plant.

The capacity of the secondary clarifier to concentrate solids can be expressed as pounds solids per day per square foot of clarifier surface area. The increased organic load on the plant due to CR will result in increased biological synthesis in the aeration tank increasing the MLSS* concentration. This increased MLSS concentration will cause the clarifier to compact the solids and becomes the governing factor in plant operations. Fig. I-8, Metcalf and Eddy (Ref.10) shows the relationship among hydraulic overflow rates, MLSS concentrations, and solids loading rates. Based on the settling rates of normal activated sludge solids, a maximum solids loading rate of 30 lb/day sq ft is typically suggested. At higher rates the capacity is exceeded, solids accumulate as a rising sludge blanket ultimately increasing the amount of solids in the effluent. A solids loading rate of 30 lb/day ft^2 was used as an estimate of the capacity of the clarifier. For a given clarifier, this value is used to determine the maximum amount of solids that can be removed by the clarifier per day for recycle to the aeration tank and hence the maximum solids that can be maintained in the aeration tank. This value is used to determine the food to micro-organism ratio as detailed later in this section.

Aeration Tank

The aeration tank maintains a proper environment for the organisms in activated sludge. This environment is usually characterized by the two major operating parameters of food to micro-organism ratio (F/M) expressed as pounds of BOD per day per pound of mixed liquor suspended solids and the dissolved oxygen level measured as milligrams of oxygen per liter of mixed liquor.

Operation of the aeration tank to produce an acceptable final effluent requires that conditions allow the sludge to settle properly in the secondary clarifier. These conditions are determined largely by the balance between the micro-organisms in the mixed liquor and the amount of influent waste they use for food. This F/M ratio should ideally be kept in the range of

* Mixed Liquor Suspended Solids.

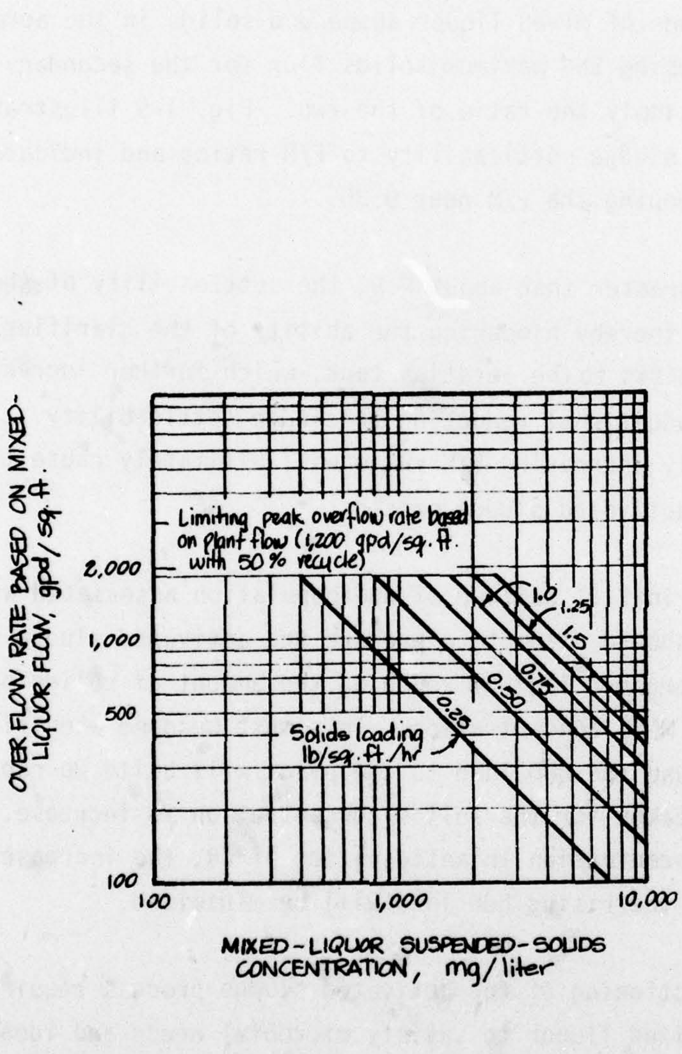

Fig. I-8. Relationships Among Surface-Loading Rates Based on Mixed-Liquor Flow in gpd/sq ft, Mixed-Liquor Suspended-Solids Concentration, and Solids Loadings for Activated-Sludge Settling Tanks.

0.3 to 0.5 for conventional activated sludge plants. The pounds of BOD entering the aeration tank can be determined from the projected organic load.* The pounds of mixed liquor suspended solids in the aeration tank are determined using the maximum solids flux for the secondary clarifier and the F/M is simply the ratio of the two. Fig. I-9 illustrates the relationship of sludge settleability to F/M ratios and indicates the desirability of keeping the F/M near 0.35.

At ratios greater than about 0.5, the settleability of the sludge may be reduced, thereby hindering the ability of the clarifier to return micro-organisms to the aeration tank, which further increases the ratio, causing additional reduction to sludge settleability. In this manner a steadily increasing F/M ratio will ultimately cause the complete failure of the activated sludge process.

During the initial buildup of the population associated with CR, the plant operator should attempt to prepare the activated sludge system for the increasing organic load by reducing the amount of solids being wasted to increase the MLSS concentration. This must be done when first notified of CR because the BOD load to the plant will build up rapidly compared to the time it takes for the solids concentration to increase. By increasing the MLSS concentration in anticipation of CR, the increase in the F/M ratio caused by the rising BOD load will be minimized.

Proper functioning of the activated sludge process requires sufficient oxygen in the mixed liquor to satisfy microbial needs and ideally maintain the dissolved oxygen concentration in the range of 1 to 3 mg/ℓ. Biological activity is independent of the dissolved oxygen content above this minimum critical range, however, below this range the metabolism of the micro-organisms, and therefore treatment, is limited by the reduced oxygen

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*For activated sludge systems that are preceded by primary sedimentation, the BOD concentration of the primary effluent will be used as the organic load of the wastewater entering the aeration tank. For activated sludge plants that do not have primary treatment, the BOD concentration of the wastewater entering the plant will be used.

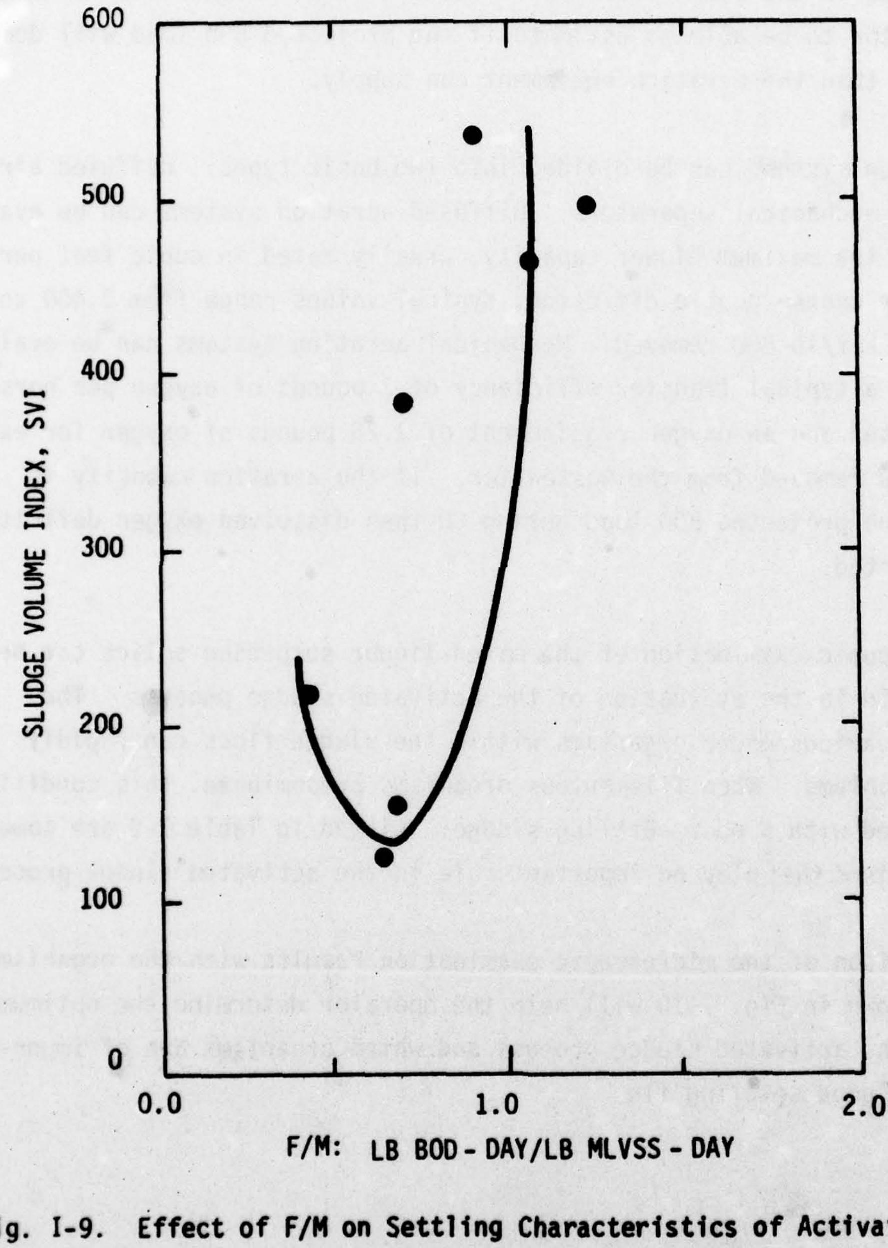


Fig. I-9. Effect of F/M on Settling Characteristics of Activated Sludge. Source: Parker, D.S. et al. (Ref. 16).

supply. In addition, the lower dissolved oxygen can result in a decline in sludge settleability by causing sludge bulking, and can result in rising sludge clumps in the final clarifier. Thus it is most important for the plant operator to be able to estimate if the projected BOD load will demand more oxygen than the aeration equipment can supply.

Aeration systems can be divided into two basic types: diffused air systems and mechanical separators. Diffused aeration systems can be evaluated using the maximum blower capacity, usually rated in cubic feet per minute. For coarse bubble diffusion, typical values range from 1,400 to 1,200 cu ft air/lb BOD removed. Mechanical aeration systems can be evaluated using a typical transfer efficiency of 2 pounds of oxygen per horsepower per hour and an oxygen requirement of 1.25 pounds of oxygen for each pound of BOD removed from the wastewater. If the aeration capacity is less than the projected BOD load during CR then dissolved oxygen deficits can be expected.

Microscopic examination of the mixed liquor suspended solids can be a helpful aid in the evaluation of the activated sludge process. The presence of various micro-organisms within the sludge flocs can rapidly indicate problems. When filamentous organisms predominate, this condition is associated with a poor settling sludge. Listed in Table I-9 are some micro-organisms that play an important role in the activated sludge process.

Comparison of the microscopic examination results with the organism balances shown in Fig. I-10 will help the operator determine the optimum range for the activated sludge process and which organisms are of importance for a good settling floc.

Table I-9

Significance of Micro-organisms in Activated Sludge

Sludge Condition	Protozoan Population
1. Bad Sludge A. Bacteria dispersal B Sludge does not flocculate	1. Preponderance of: A. Flagellated amoeba and B. Other Rhizopods 2. Relatively few ciliates
2. Unsatisfactory Condition A. Bacteria dispersal B. Some flocculation	1. Present: A. Flagellates B. Amoeba and other rhizopods 2. Some ciliates A. Free-swimmers B. Stalked
3. Satisfactory Condition A. Bacteria flocculate B. Improved sludge settleability	1. Few: A. Flagellates B. Amoeba and other rhizopods 2. Preponderance of free-swimming ciliates 3. Some stalked ciliates
4. Good Condition A. Good sludge settleability B. Effluent 5-day BOD low	1. Very few flagellates 2. Some free-swimming ciliates 3. Preponderance of stalked ciliates 4. Few rotifers

Source: Linn Benton Community College (Ref. 17).

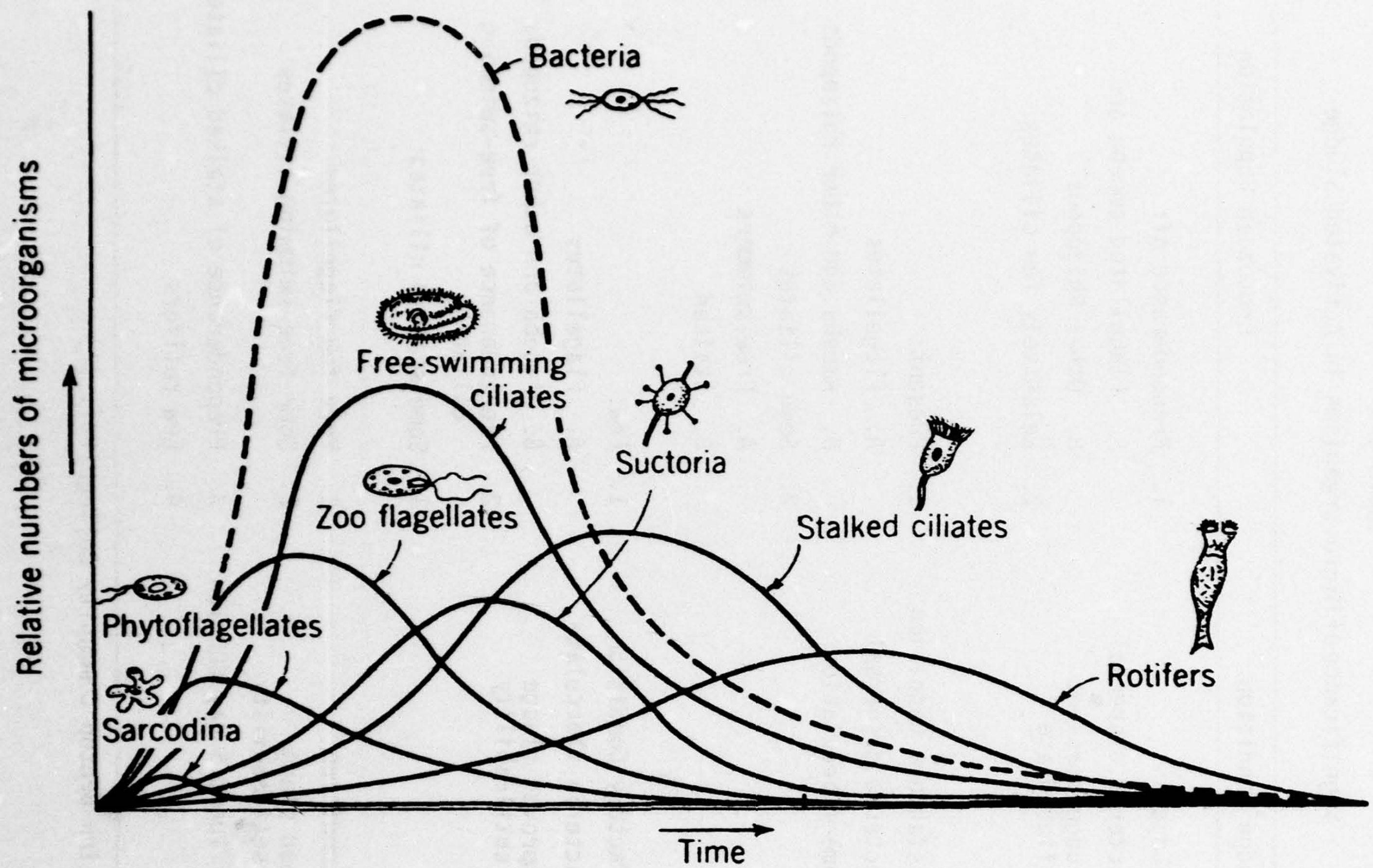


Fig. I-10. Optimum Microorganisms Balance for Activated Sludge.
Source: McKinney (Ref. 18).

WASTE TREATMENT PONDS AND LAGOONS

Ponds and lagoons are earthen basins designed to retain wastes while biological treatment takes place. The EPA (Ref. 19) states that there are currently over 4,000 publicly owned ponds and lagoons in the United States; most of these are located in small communities and have design flows less than 1 mgd. There are many variations of waste treatment ponds and lagoons, but they are often divided into the following four general categories, based on the nature of the biological activity that is taking place:

1. Aerobic pond (also called photosynthetic pond)
2. Facultative pond (also called aerobic-anaerobic stabilization pond)
3. Anaerobic pond
4. Aerated lagoons.

For this study, lagoons are considered to be artificially aerated (number 4) whereas ponds are non-aerated (numbers 1, 2, and 3). The division among the three types of ponds is somewhat arbitrary and the general characteristics for each are given here.

Ponds

Ponds use natural aeration, primarily algal photosynthesis, to provide oxygen. However, heavily loaded ponds sometimes have supplemental aeration equipment to help maintain dissolved oxygen concentration and to periodically mix the wastewater. These would be analyzed as lagoons. The usual design criteria for ponds are population per acre loading or areal BOD loading. Because of wide variations in temperature and sunlight intensity throughout the country, state design guidelines vary greatly. Table I-10 lists typical design values for facultative ponds showing the effects of climate and location.

Table I-10

Typical Design Values for Oxidation Ponds

Location	Population Loading (People/acre)	BOD Loading lb BOD/acre-day
South Dakota	100	20
Oklahoma	200	--
Missouri River Basin	400	45
Texas	450	50

Source: Environmental Protection Agency, (Ref. 20), and Metcalf and Eddy, (Ref. 10)

An anaerobic pond is a relatively shallow (12 to 18 in.) body of water, generally with a long hydraulic detention time (10 to 40 days). The shallow depth allows algae to provide oxygen for aerobic bacteria throughout the entire pond. Being shallow, these ponds are very land-intensive so that the majority of ponds used in waste treatment are facultative ponds. Ideally, these ponds maintain three biological zones: an aerobic surface zone where bacteria and algae exist in a symbiotic relationship; an anaerobic bottom zone where accumulated solids are decomposed by anaerobic bacteria; and an intermediate zone containing both aerobic and anaerobic bacteria. To maintain the aerobic zone, organic loadings are generally in the range of 20 lb to 50 lb BOD/acre-day. This corresponds to a population loading of approximately 100 to 300 persons per acre of surface area for ponds without primary treatment and 150 to 450 persons per acre with primary treatment.

Because anaerobic ponds do not require aerobic conditions, they have the highest organic loadings — typically in the range of 200 lb to 1,000 lb BOD per acre per day. The high organic loadings are necessary to

maintain anaerobic conditions throughout the ponds, and warm temperatures (75° F minimum) are required to maintain a population of methane bacteria. Anaerobic ponds have been used extensivley to treat high-temperature, high-strength industrial wastes, such as those from the meat packing industry. Because of the relatively low BOD concentration and cool temperature of domestic wastewater, anaerobic ponds are seldom used to treat municipal waste.

Although there are many variations of ponds, they all exhibit certain general operating characteristics, i.e., treatment efficiency is affected most notably by the organic loading, hydraulic detention time, temperature of the wastewater, and sunlight intensity. Because of these interrrelated factors, effluent quality cannot always be related simply to the organic loading and in some cases, as loadings are increased, effluent quality may not change significantly. Of the treatment processes examined in this report, ponds and lagoons are generallly the least sensitive to overloads resulting from CR. However, it should be noted that at lower temperatures, the rate of biological activity is reduced, so that CR could have an impact on ponds.

Because it is difficult to quantify the effects of the numerous environmental factors that influence pond performance, a regression model developed to relate BOD removal efficiency to hydraulic detention time and areal organic loading was adapted to describe the effects of CR. Equation 1, adapted from Parker et al. (Ref. 16) represents an operational relationship developed for all three types of ponds.

$$E = k\, Y^{-0.082}\, T^{0.121} \qquad \text{(Equation 1)}$$

where E = BOD removal efficiency

k = local plant operational constant

Y = BOD loading in lb BOD/acre-day

T = hydraulic detention time in days.

In order to ensure proper operation of ponds designed using this equation, Parker, et al. suggested the limitations listed in Table I-11:

Table I-11

Suggested Range of Conditions for Ponds Designed Using Equation 1

Pond Type	Range of BOD Removal Efficiency	Maximum Depth
Aerobic	68 - 96	3 ft
Facultative	60 - 90	6 ft
Anaerobic	50 - 80	12 ft

To simplify the calculations that must be made by the plant operator, a graphical presentation of the functions $Y^{0.082}$ (Fig. I-11) and $T^{0.121}$ (Fig. I-12) were plotted. The term, $Y^{0.082}$ is replaced by a variable designated "A" and similarly the term, $T^{0.121}$ is replaced by "B". Using the graphical functions, the parameters in Equation 1 can be determined without performing exponential mathematical calculations.

The pre-CR efficiency of a pond is influenced by many environmental factors and by the process loading. Because environmental conditions are unchanged during CR, the efficiency of a pond will be influenced only by the increased loads.

The change in pond efficiency during CR will be predicted, assuming the effect of the increased organic and hydraulic loads are described by Equation 1. That is, the ratio of the pre-CR and CR pond efficiencies is

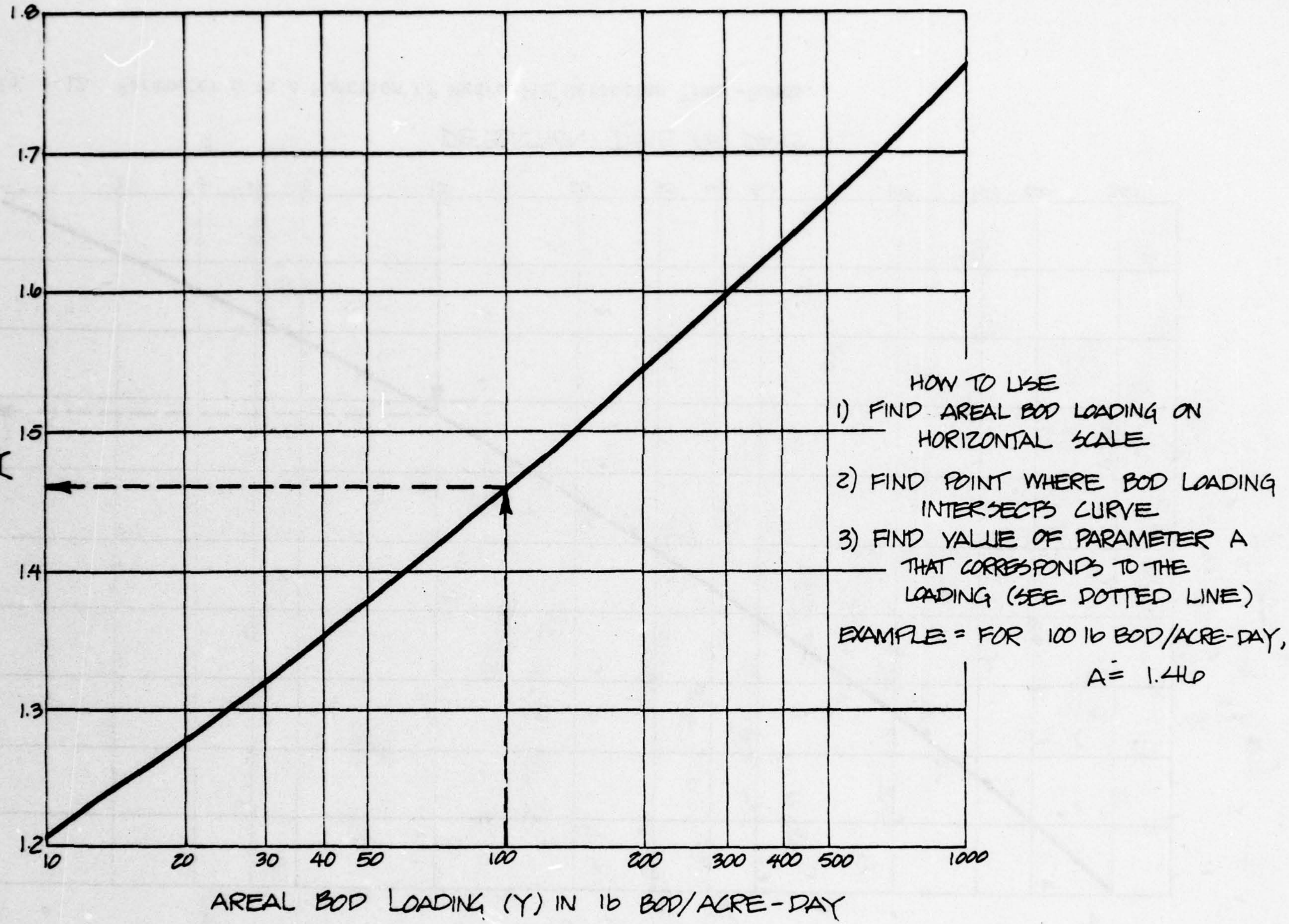


Fig. I-11. Parameter A as a Function of Areal BOD Loading - Ponds.

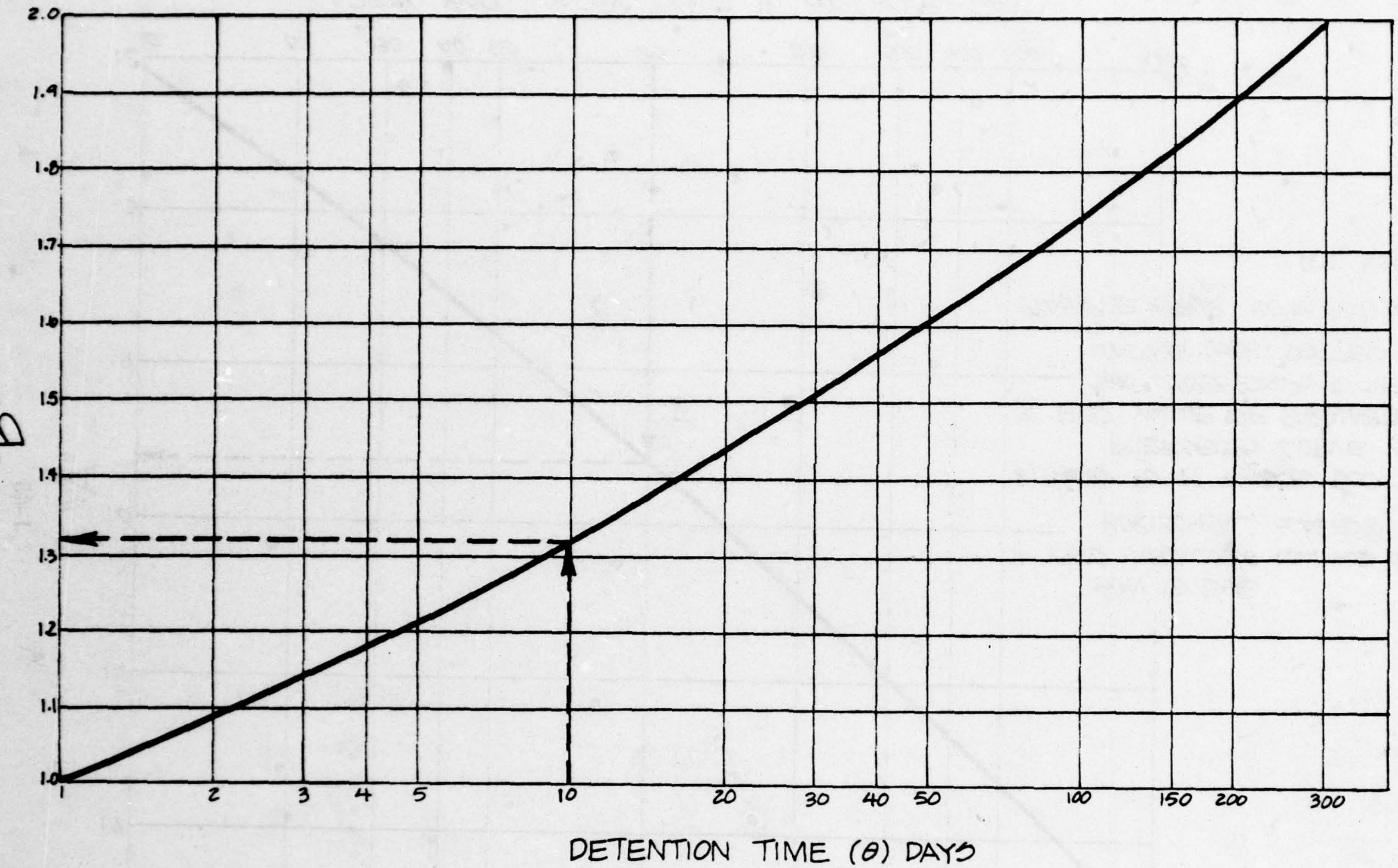


Fig. I-12. Parameter B as a Function of Hydraulic Detention Time -Ponds.

equal to the product of the ratios of pre-CR and CR values of the variables A and B. The following sample calculation is an example of how this approach can be used to rapidly determine the expected decrease in treatment efficiency which will result from projected CR conditions.

Sample Calculation

1. Pre-CR values
   A. BOD removal efficiency - 85%
   B. BOD loading = 40 lb BOD/acre-day
   C. From Graph I, for 40 lb BOD/acre-day, A = 1.355
   D. Detention time = 10 days
   E. From Graph II, for 10 days, B = 1.32
2. CR Values
   A. From worksheets, BOD loading = 100 lb BOD/acre-day
   B. From Graph I, for 100 lb BOD/acre-day, A = 1.452
   C. From worksheets, detention time = 4 days
   D. From Graph II, for 4 days, B = 1.18
3. Removal efficiencies
   A. Effect of increase in BOD load

$$\left(\frac{\text{pre-CR "A" } \underline{1.355}}{\text{CR "A" } \underline{1.452}}\right) = \underline{R_1 = .93}$$

   B. Effect of decrease in detention time

$$\left(\frac{\text{CR "B" } \underline{1.18}}{\text{Pre-CR "B" } \underline{1.32}}\right) = \underline{R_2 = .89}$$

   C. CR removal efficiency

$$(\text{Pre-CR removal [1a]}) \times R_1 \times R_2 = \underline{\text{CR efficiency}}$$

$$85\% \times .93 \times .89 = 70.7\%$$

Lagoons

Lagoons are similar to ponds, but usually have shorter detention times and higher BOD loadings because artificial aeration is used to supply greater amounts of oxygen for bacterial growth. Algae are sometimes present, but they are not the main source of oxygen.

A lagoon is a very stable system that will experience only slowly decreasing treatment with increased loading. If sufficient aeration capacity is available to maintain aerobic conditions, the major variable affecting performance is the hydraulic detention time. The effect of detention time on lagoon treatment efficiency is usually described using first-order kinetics and assuming a completely mixed basin. For such a system, the effect of detention time on treatment efficiency can be described using Equation 2:

$$E = \frac{1}{1 + k\Theta} \qquad \text{(Equation 2)}$$

Where E = fraction of BOD remaining after treatment

k = rate constant

Θ = detention time

The system's rate constant, k, describes the ability of the system to treat wastes and is a function of temperature, waste character, and similar factors. Existing pre-CR conditions (E and Θ) are used to calculate the rate constant for the system from Equation 2. Using this rate constant and the CR detention time, Equation 2 is used to estimate the CR efficiency.

In addition to the detention time, the adequacy of the aeration capacity will affect lagoon performance. If aerobic conditions cannot be maintained, then biological rates will be somewhat reduced and odors can develop. The efficiency of aeration equipment varies, but a general rule of thumb is 1 pound of oxygen per horsepower-hour; to remove 1 pound of BOD requires approximately 1.5 pounds of oxygen. Using these values, the capacity of the aeration equipment was estimated and then compared to the organic load imposed on the system.

SOLIDS HANDLING

A major problem facing the plant operator during CR will be the treatment and disposal of the sludge produced by the various treatment processes. The sources of sludge considered in this study are the primary clarifier and secondary clarifier associated with either trickling filter or activated sludge systems. Table I-12 (Metcalf and Eddy, Ref. 10) lists typical values for sludge production.

Table I-12

Typical Sludge Quantities Produced by Different Treatment Processes

Process	Gal Sludge Per Million Gal Treated	Lb Dry Solids Per Mil. Gal Treated		Cu Ft Sludge Per 1,000 People Daily	Lb Sludge Per 1,000 People Daily
Primary	2,950	1,250	95	39	125
Trickling Filter	745	476	92.5	9.9	48
Activated Sludge	19,400	2,250	98.5	258	225
Primary and Activated Sludge	6,900	2,340	96	92	234

The main objective in any solids handling process is the stabilization and/or disposal of the raw untreated sludges by biological or chemical means to significantly reduce organic solids, pathogenic organisms, and odor. Anaerobic digestion is the most frequently used method of stabilization, but there are numerous other methods including aerobic digestion, sludge lagoons, and lime or chlorine treatment. After stabilization, the treated sludge is usually pumped to some type of dewatering or drying process.

In order to evaluate the solids handling operations, the total daily sludge production during CR must be determined. It will be assumed that

the concentration of the sludge will not change significantly during CR. Thus the volume of sludge produced by each process during CR will be determined using the pre-CR solids concentration and the average CR flow. The sludge volumes calculated in each process worksheet are then compiled in the sludge handling worksheet for easy reference. The total sludge volume can then be compared to typical pre-CR values to determine the approximate increase in equipment operation time and labor necessary to handle the load. The total volume can also be compared to digester capacities to determine the detention time in the digester. This is discussed in greater detail in the section on digestion.

If the total sludge volume anticipated during CR cannot be handled, primary sludge must be given priority in treatment as it represents the greatest problem with respect to pathogenic organisms. The untreated secondary sludge can be mixed with digested sludge in temporary lagoons resulting in some degree of treatment. In this situation, the sludge lagoon serves partially as an "open air" digester.

SLUDGE DIGESTION

The purpose of the various sludge digestion processes is to convert untreated primary and secondary sludge into a relatively inert humus-like material. The treated sludge is less offensive with respect to odor and pathogen content. The amount of dry sludge solids is considerably reduced by the digestion process. In the United States today the most common process is anaerobic digestion, but the use of aerobic digestion is growing, particularly in small activated sludge plants. These two processes will be discussed separately.

Anaerobic Digestion

Anaerobic digestion of waste organic matter is carried out in two phases which occur simultaneously in a properly balanced digester. The waste matter is first converted into volatile acids by the acid-forming bacteria and then these organic acids are utilized by the methane-forming

bacteria to produce methane and carbon dioxide gas (see Fig. I-13). The methane-formers are very sensitive to changes in load, pH, and temperature and have a much slower growth rate than the acid-formers. The stability of the process relies on the proper balance of the two populations of bacteria. With the rapidly increasing organic loads associated with CR, the acid-formers (which are relatively insensitive to changes in load and environmental conditions) can produce quantities of volatile acids in excess of the assimilative capacity of the methane-formers causing an accumulation of volatile acids which potentially can lower the pH in the digester. A pH drop much below 6.6 results in an environment that is hostile to the methane-formers reducing their capacity to convert volatile acids to methane and further lowering the pH. This trend will eventually lead to a complete process failure.

Anaerobic digestion can be divided into single-stage or two-stage processes. Single-stage digesters, shown in Fig. I-14, generally represent older designs found in plants of 1 mgd or less where the functions of digestion, sludge thickening, and supernatant formation are carried out simultaneously in the same tank. Because of the stratification in the tank, usually no more than 50% of the total volume is used for digestion. Because of this mode of operation it is difficult to evaluate the true capacity of a single-stage digester at any given time. For this reason, potential host communities served by plants with a single-stage digester should be avoided where possible as it will be difficult to quantify the maximum plant capacity. However, single-stage digesters can be modified by adding gas mixing equipment which provides some degree of control (see discussion in the section on new construction modifications).

Because of the problems with single-stage digesters, most conventional digestion is carried out as a two-stage process, as shown in Fig. I-15. Here one tank is used for digestion and the other is used for storage and concentration of the digested sludge and for the formation of a relatively solids free supernatant. By separating the functions, the digestion process in the first tank can be more carefully controlled and its capacity more easily determined. The second tank is generally unheated,

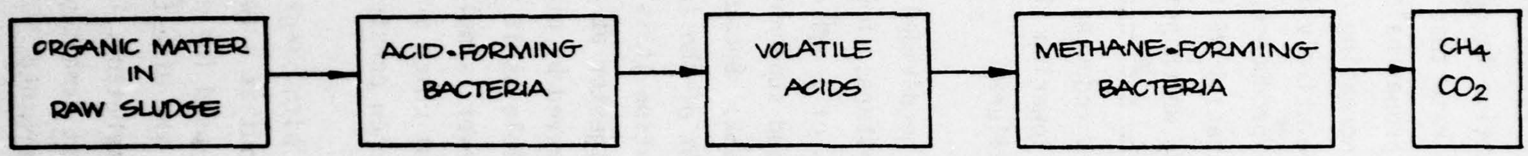
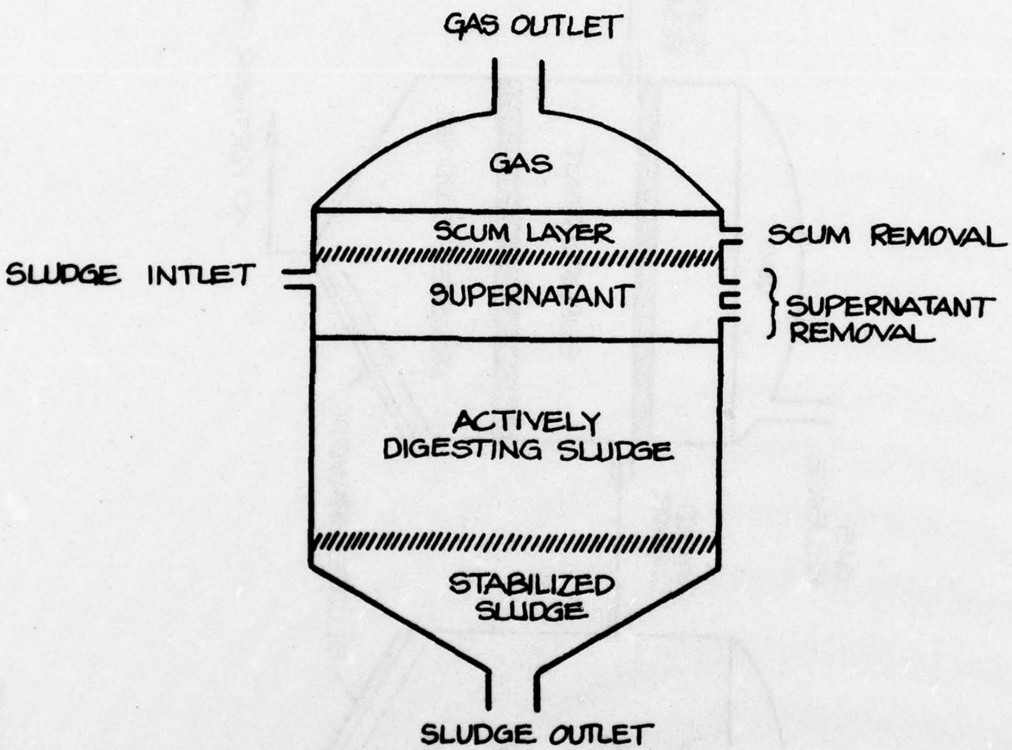


Fig. I-13. Anaerobic Digestion Process.



(A)

STANDARD RATE DIGESTION

1. UNHEATED
2. DETENTION TIME 30 - 60 DAYS
3. LOADING 0.03 - 0.10 lb. VSS/cu.ft./day
4. INTERMITTENT FEEDING AND WITHDRAWAL
5. STRATIFICATION

Fig. I-14. Single-Stage Anaerobic Digester.

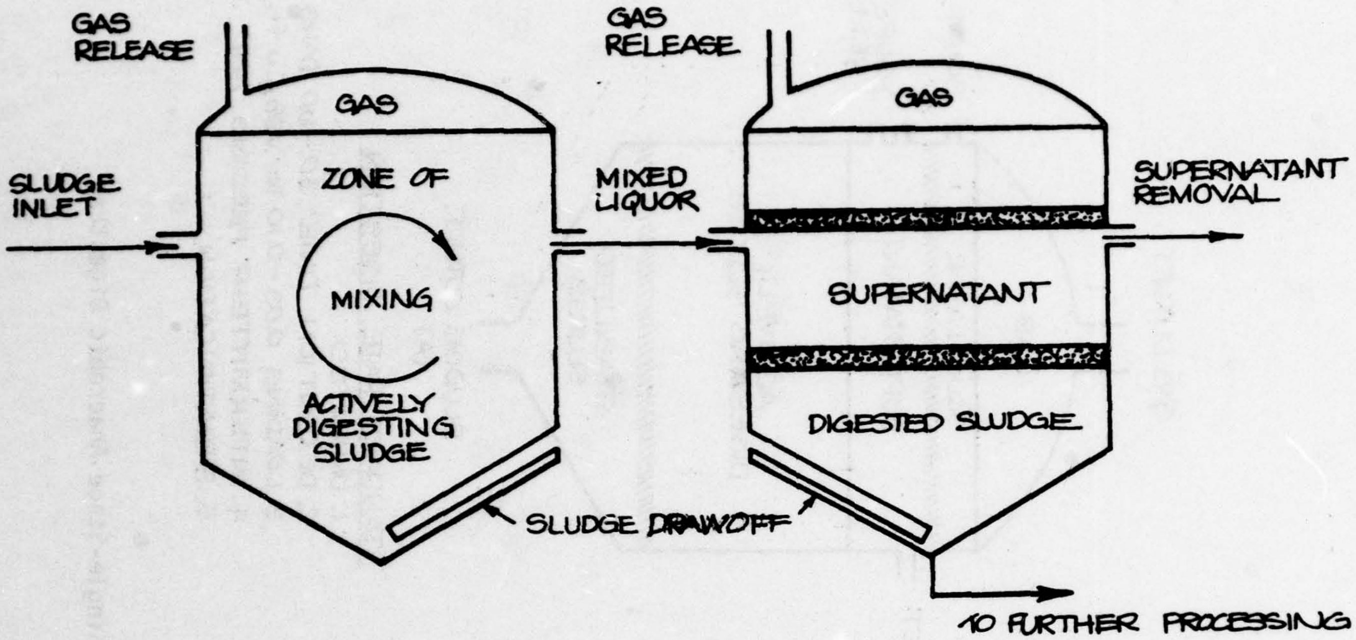


Fig. I-15. Two-Stage Anaerobic Digester.

may be open to the atmosphere, and in some locations is simply a sludge lagoon.

The operation of the anaerobic digester is relatively independent of the hydraulic flow. However, an increase in the primary or secondary effluent suspended solids immediately affects the digester by causing a proportionate increase in the waste solids stream. The primary effect of the increase in the waste solids stream is to decrease the digester detention time which, as shown in Fig. I-16, causes a decrease in the treatment. Furthermore, if an increase in solids decreases the digester detention time much below 7 days, the process can be expected to approach a failure condition.

An estimate of the daily volume of sludge produced by the plant treatment processes is made in the manual worksheets in order to evaluate the capacity of the digester and the sludge pumps. If treatment is limited either by the pumping capacity or the digester, then alternative methods of sludge disposal such as temporary lagoons must be considered. Because digesters are subject to total failure when stressed, their maximum capacity may be the limiting factor determining the maximum population that can be adequately served by the plant.

If the projected sludge volumes are greater (refer to solids handling worksheet in the manual) than can be handled by the existing digester facilities while maintaining a detention time greater than 7 days, then the sludge volumes must either be reduced (refer to discussion on load reduction) or some sludge must bypass the digester. Secondary sludge is the preferred sludge to bypass the digester because it has less nuisance value and contains fewer pathogens. Combining the bypassed sludge with the treated sludge after digestion can result in some treatment of the bypassed sludge if the mixture is maintained in a secondary digester, sludge lagoon, or similar storage.

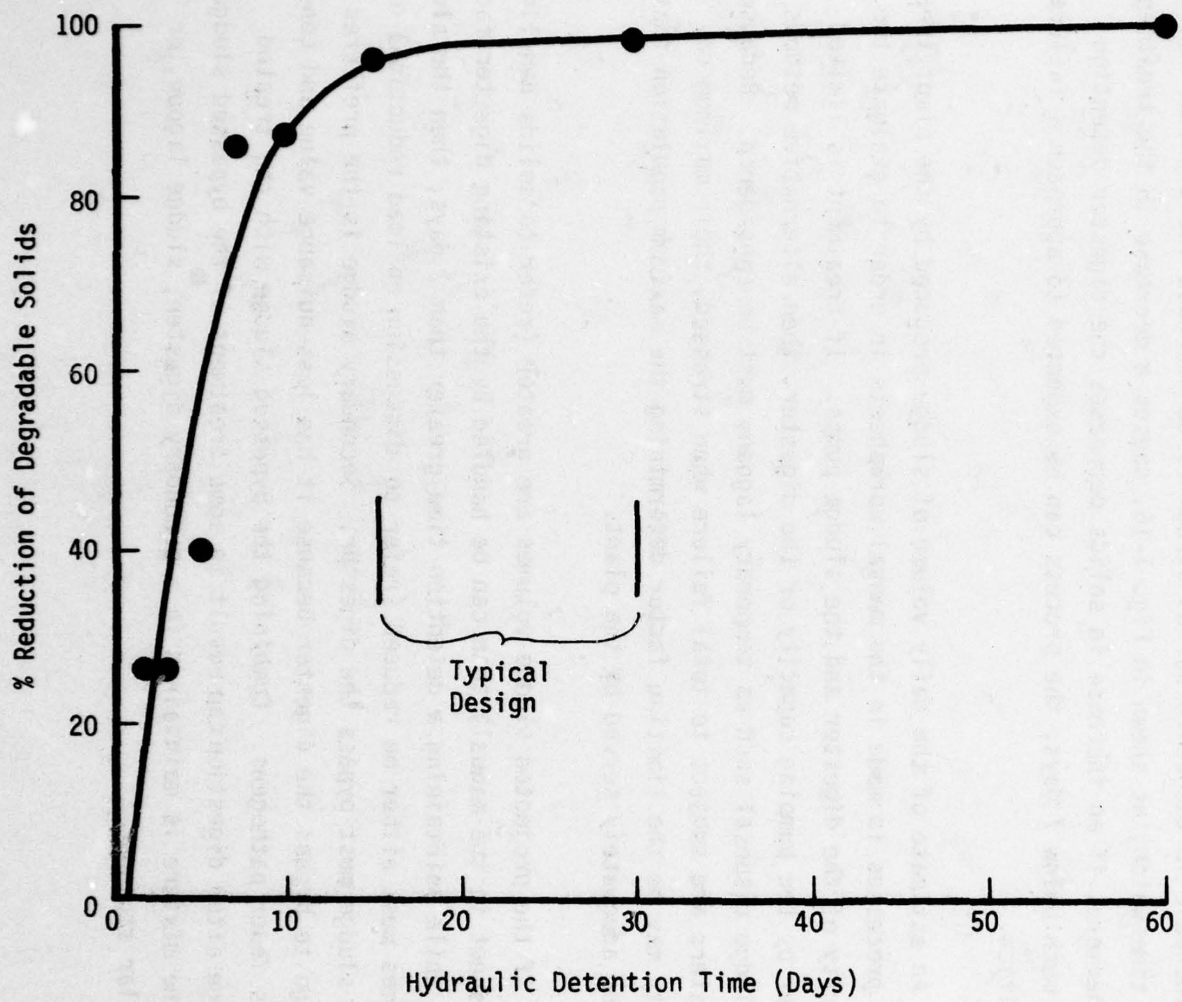


Fig. I-16. Performance Data for an Anaerobic Digester.

Aerobic Digestion

Aerobic digesters are designed as a complete-mix activated sludge process for the separate aeration and stabilization of waste sludges. They are commonly used in small package plants to treat waste activated sludge which is highly aerobic in nature, has a low solids concentration, and thus does not lend itself to conventional anaerobic treatment. As in an activated sludge system, oxygen is supplied to the process either by mechanical or diffused aeration equipment. A minimum dissolved oxygen concentration of 1 to 2 mg/ℓ is considered necessary for adequate treatment. Stabilization requires an extended period of aeration varying from 10 to 20 days, depending on the nature and source of the sludge (i.e., primary, secondary, or a combination). Typically, a 35% to 45% reduction in organic solids can be achieved in 10 to 12 days at temperatures of $20^{o}C$ or higher. Solids reduction continues at a considerably reduced rate as the detention time is increased above 12 days, as shown in Fig. I-17. At lower temperatures, the detention time must be increased to maintain the same level of treatment because of the slower rate of biological activity.

The increased loadings during CR will result in lower detention times, greater demands on the aeration equipment and a corresponding reduction in treatment. However, because of the wide variations in operating conditions, it is impossible to quantify a reduction in efficiency with respect to detention time or aeration capacity. As the detention time drops rapidly, but unlike anaerobic digestion, a complete failure of the process will not occur.

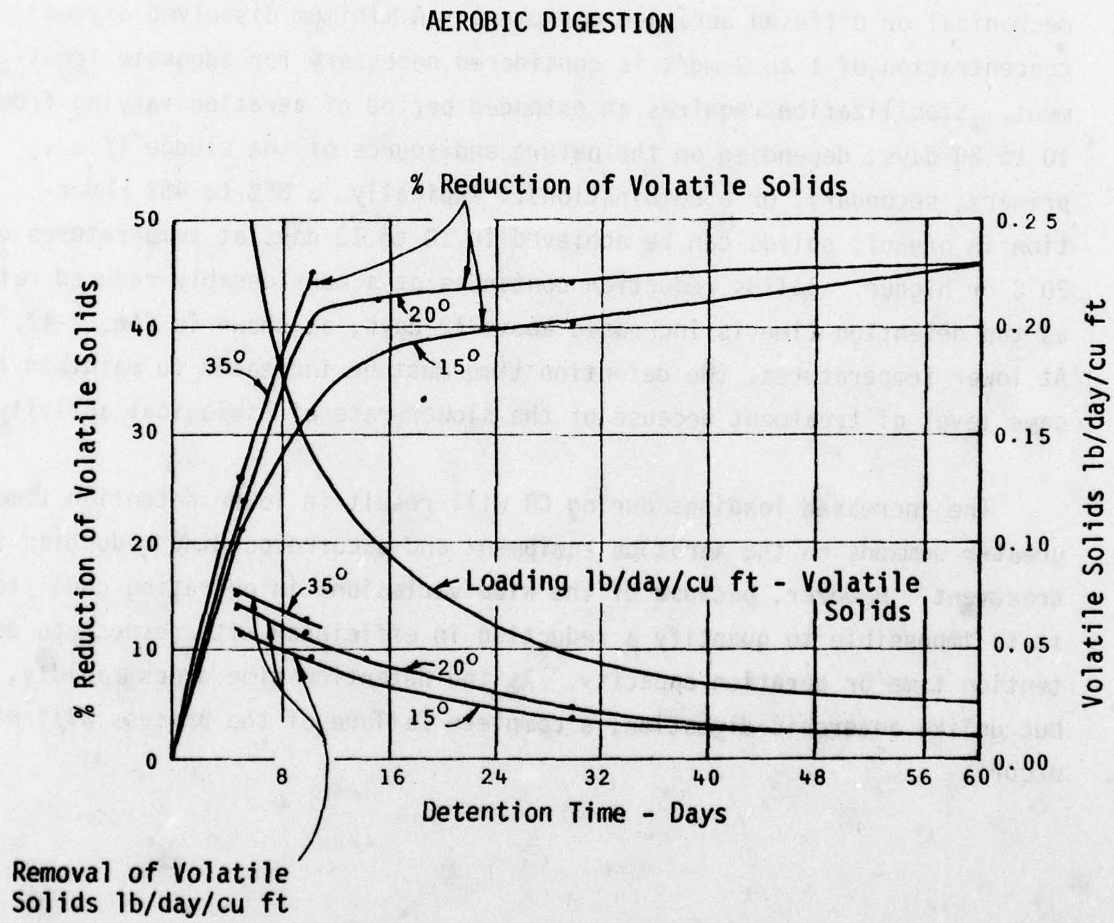


Fig. I-17. Effect of Time and Temperature on the Volatile Solids Content of Aerated Sludge. (Lb/day/cu ft x 16 = kg/day/cu m.)

Source: Lawton (Ref. 21).

PUBLIC HEALTH

The first goal of sewage treatment is the prevention of waterborne disease. A properly designed and operated treatment plant will accomplish this objective. However, during CR, increased waste production can overtax the treatment facilities. Unless adequate measures are taken, this could lead to less efficient pathogen removal and destruction creating a greater potential for the transmission of waterborne enteric diseases. Private sewerage systems, such as septic tanks, also may be overloaded by the influx of relocatees, causing an added strain on these systems.

The potential for any given disease being spread during CR due to insufficient waste treatment depends upon: (1) the incidence of that disease in the population served by a treatment plant; (2) the removal efficiencies of the various treatment processes; and (3) the possible modes of transmission. This section will briefly discuss each of the above three issues.

Incidence of Disease

Data on the incidence of various diseases attributed to drinking water in the United States are given in Table I-13. These data show that gastrointestinal diseases, shigellosis, and hepatitis are the major diseases of concern with typhoid having the lowest incidence. Fortunately, most of the typhoid carriers are documented with public health officials, thus allowing special planning for the relocation of these individuals to minimize the public health impact of their relocation. Other known diseases which may be spread through wastewater discharges are cholera, polio, and tuberculosis.

Modes of Transmission

The transmission of disease from a sewage treatment facility usually occurs by either of two mechanisms: contamination of a water supply by waterborne organisms or contamination of food by vectorborne (usually

Table I-13

Outbreaks of Disease Attributed to Drinking Water in the U.S. 1920-1970

	1920-1936	1938-1945	1946-1960	1961-1970	1976***
No. of outbreaks	399	327	228	130	35
No. persons involved	116,000	111,000	25,984	46,374	5,068
No. of deaths	960	--	16	20	--
Percent of cases					
Gastrointestinal	88	91	72(58)**	57(30)	29(74)
Typhoid	11	1	1.9(17)	0.2(11)	15(3)
Hepatitis	--*	--	4(10)	2(23)	0(0)
Shigellosis	1	8	22(5)	4(15)	43(6)
Semi-public & private					
Percent of outbreaks	--	70	69	73	74
Percent of cases	--	10	23	14	26

* 1 outbreak of 28 cases

** Figures in parentheses refer to percentage of outbreaks.

*** Center for Disease Control, "Foodborne and Waterborne Disease Outbreaks", Annual Summary 1976.

flies) organisms. Transmission via water is the usual mechanism of contamination and can occur due to the mixing of sewage effluents with surface receiving waters or due to the contamination of ground waters by seepage from lagoons or land disposal sites. As will be seen in a succeeding discussion, the majority of the influent organisms are removed during primary and secondary treatment with only a small fraction being discharged into the receiving waters.

Even though sewage effluents are vastly diluted when mixed with receiving waters, and even though the number of organisms are further reduced in natural waters by sedimentation, exposure to light and low temperatures, predation by aquatic animals, and simple starvation through the lack of nutrients, the small fraction discharged into receiving waters do, however, pose a threat to public health because of the direct contamination of surface waters. Because of this, proper disinfection of the liquid effluent is required. This will require a greater consumption of chlorine during CR, which is discussed in the section on chlorination.

Pathogen Removals by Treatment Process

Representative removals of selected organisms by various treatment systems are presented in Table I-14.

Table I-14

Estimated Wastewater Pathogens*

Pathogen	Raw Wastewater	Primary Effluent	Secondary Effluent	Disinfection**
Salmonella (typhoid)	2×10^{10}	1×10^{10}	5.0×10^{8}	5.0×10^{5}
Mycobacterium	2×10^{8}	1×10^{8}	1.5×10^{7}	1.5×10^{4}
Virus	4×10^{10}	2×10^{10}	1.0×10^{9}	2.0×10^{6}

*The term pathogen is used to describe bacteria and viruses capable of causing human or animal infection.

**Conditions sufficient to yield a 99.9% kill.

Source: Elliot, L.F. and J.R. Ellis, 1977 (Ref. 22).

These data indicate that about 50% of the influent pathogens are removed during primary sedimentation and approximately 45% are removed during biological treatment resulting in approximately 95% overall removal efficiency. This section briefly discusses the public health issues of various treatment processes.

Primary sedimentation which is used in most communities removes about half of the pathogens. Studies show that no significant reduction of pathogens occurs during the first 3 hours of primary sedimentation, but that some reduction occurs between 6 and 24 hours of settling. Within this period, large amounts of pathogens are removed by settling in the primary clarifier. Since about 50% of the pathogens are removed in the primary clarifier, this also means that the primary sludge will contain about 50% of the pathogens.

During CR, the detention time in the sedimentation basin will drop off which will affect the removal efficiency of pathogens. Due to the increased CR hydraulic load, the use of chemical coagulants can increase the amount of solids and pathogens removed. However, chemical coagulation and flocculation cannot be expected to operate with a high degree of efficiency in terms of pathogen removal when the wastewater contains high organic matter.

Unfortunately, no actual destruction of pathogens occurs during sedimentation. Because pathogens remain active in the settled sludge following their removal from wastewater by coagulation and flocculation, care must be taken in the disposal and handling of sludge as discussed later in this section.

Biological treatment systems such as activated sludge, trickling filters, and stabilization ponds are more effective than sedimentation in the removal of pathogens. They provide not only destruction of pathogens via predation by the biological organisms but also settling in the secondary sedimentation. The greatest removal of pathogens in biological treatment comes as a result of their adsorption onto sludge particles. However, only

after an indefinite time can the complete removal of pathogens be accomplished in this manner alone. Removals of pathogens in ponds are thought to be the result of adsorption, chemical insults, destructive rays of sunlight, warm temperature, and time in variable combinations. Thus where land is plentiful, stabilization ponds often can serve as secondary treatment. With 20 days retention time, stabilization ponds generally are a very effective pathogen treatment.

Because there will be greater volumes of sludge produced and less treatment of these sludges, the potential for contamination from these sludges will also be increased. Although the removal of pathogens by primary and secondary treatment are nearly identical, the secondary treatment provides pathogen destruction via predation while primary treatment does not. Thus from a public health standpoint, the treatment and disposal of primary sludges has a higher priority than the treatment and disposal of secondary sludges assuming adequate removal time is allowed in the biological treatment processes. Therefore, if the volume of sludge produced during CR is greater than the capacity of the digester, alternative treatments or disposal of the secondary sludge should be explored while providing complete digestion of the primary sludges. The digestion of sludges should be sufficient for inactivation of pathogens if allowed 8 to 10 days at temperatures of 85°F to 135°F (37°C to 50°C) with 85°F to 100°F being the most common. Even with adequate digestion, sludge disposal must be done carefully so as not to permit surface runoff to pollute streams and lakes.

Because the influent pathogen concentration is very high, large quantities potentially remain after primary and secondary treatment. Thus chlorination of the effluent is normally practiced to reduce the pathogen level to acceptable levels. The next section discusses various issues relating to chlorination.

CHLORINATION

The primary concern in wastewater treatment, especially during CR, is the prevention of waterborne disease. There are extensive historical accounts of transmission of typhoid and other enteric diseases by the ingestion of contaminated water. With the increased population expected during CR there will be a greater demand placed on water and wastewater disinfection. The major disinfecting agents used in wastewater treatment are chlorine (Cl_2) and its derivatives. These chemicals are strong oxidants and are non-selective microbial poisons. Because of these properties, chlorine finds wider application in wastewater treatment than just disinfection. Some of these uses are outlined in Table I-15. However, because of the increased demand for chlorine as a disinfectant during CR, these secondary applications should be minimized to conserve the treatment plant's existing supply of chlorine.

The consumption of chlorine used as a disinfectant can be broken down into two major parts: the chlorine demand and the chlorine residual. Being chemically reactive, a large portion of the chlorine added to wastewater is consumed by reactions with various constituents in the waste. The amount of chlorine required for these reactions is called chlorine demand and is usually not available for disinfection. Representative values for various chlorine demands are presented in Table I-16. The amount of chlorine added over and above these demands is called the chlorine residual and is available for disinfection. The chlorine dose is then the sum of the chlorine demand and the chlorine residual.

Wastewater is disinfected by mixing it with the chlorine and then holding the chlorinated wastewater in a chlorine contact tank to provide the time required for disinfection prior to discharge. As shown in Fig. I-18, the effectiveness of chlorination is enhanced by increases both in residual chlorine concentration and in the contact time. The rate of disinfection is also affected by temperature, the pH of wastewater, the amount of BOD in the wastewater, and the initial bacterial population; but,

Table I-15

Uses and Dosage of Chlorine in a Wastewater Treatment Plant

Chlorine Use	Specific Application	Dosage in PPM	Recommended Residual in PPM
1. Disinfection	A. Remove pathogen organisms from treatment plant	Depends on local conditions and permit requirements	Depends on local conditions and permit requirements
2. Prevention of Sewage Decomposition	A. Odor Control at:		
	1. Sewers and influent point	1. 1.5 - 10	0
	2. Overload secondary treatment facilities	2. 5 - 10	0
	B. Protection of plant structures by controlling corrosion		
	C. Sludge thickening		
3. Upgrading Plant Operations	A. Sedimentation		
	B. Trickling filters		
	1. Odor control	1. 2 - 6	0
	2. Filter ponding & clogging	2. 5 - 40	1 - 2
	3. Trickling filter flies	3. 3 - 10	0.1
	C. Activated Sludge		
	1. Sludge bulking control	1. 2 - 8	0
	2. Sludge thickening	2. Variable	1.0
	D. Imhoff tank foaming	3 - 15	0
	E. Grease Separation		

Source: Environmental Protection Agency (Ref. 23).

Table I-16

Chlorine Demand for Various Wastewater Processes

A rule-of-thumb estimate of chlorine demand for various wastewater is as follows:

Raw fresh domestic waste	8 - 15 ppm
Raw septic domestic waste	15 - 30 ppm
Primary sedimentation effluent	8 - 15 ppm
Recirculated biofilter effluent	5 - 8 ppm
Biofilter effluent (secondary)	3 - 8 ppm
Trickling filter effluent	3 - 10 ppm
Activated sludge effluent	2 - 8 ppm
Sand filtered effluent	1 - 5 ppm
Septic tank effluent	30 - 45 ppm

These figures are based upon the immediate appearance of color using orthotolidine after a 15-minute contact time. These values are adequate for choosing equipment capacity. Special situations should be investigated on an individual basis.

Source: White, G.C. (Ref. 24)

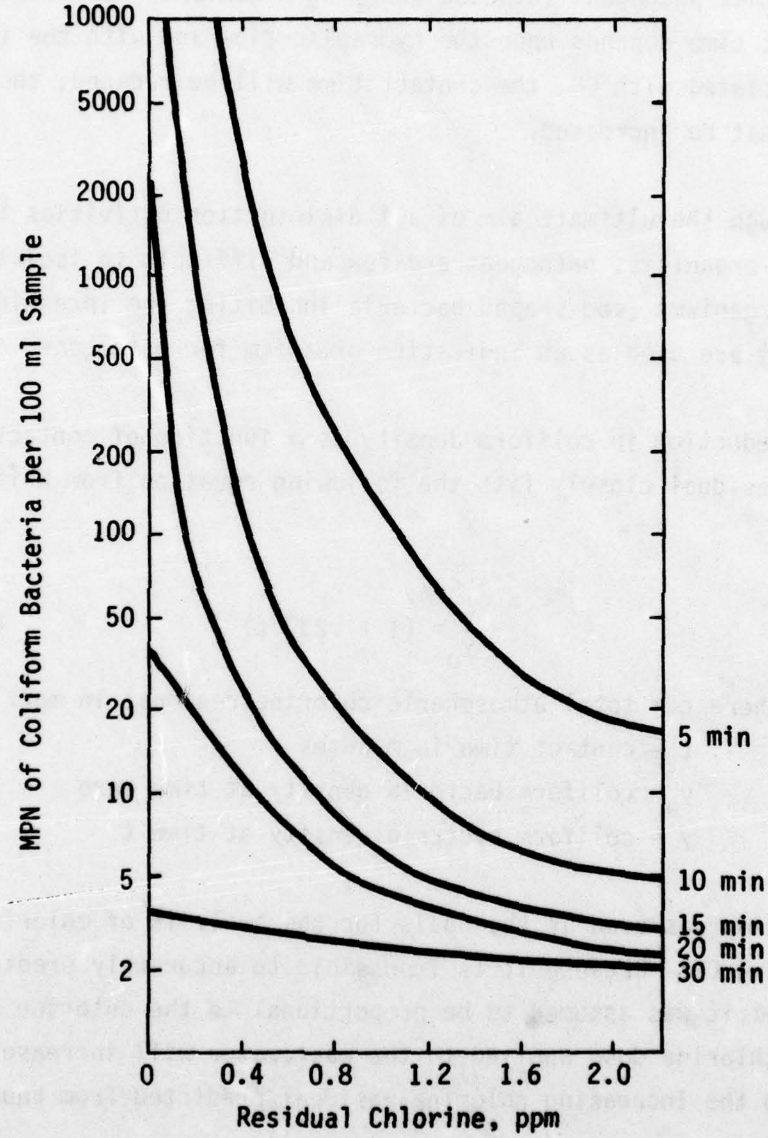


Fig. I-18. MPN Coliform Bacteria Versus Residual Chlorine After Residence Time of 5 to 30 Minutes.

Source: White, G. C. (Ref. 24).

these variables cannot be controlled by the plant operator. Detention time in the chlorine contact chamber should provide sufficient "contact time" to insure that pathogens (disease-carrying organisms) have been killed. The contact time depends upon the hydraulic flow and with the increased flows associated with CR, the contact time will be reduced; thus the chlorine dose must be increased.

Although the ultimate aim of all disinfection activities is to destroy pathogenic organisms, pathogens are few and difficult to isolate. Thus coliform organisms (rod-shaped bacteria inhabiting the intestinal tract of all humans) are used as an indication organism for pathogens.

The reduction in coliform density as a function of contact time and chlorine residual closely fits the following equation from White (Ref. 24, p. 427):

$$\frac{y}{y_0} = (1 + .23\ ct)^{-3} \qquad \text{(Equation 3)}$$

Where c = total atmospheric chlorine residual in mg/ℓ

t = contact time in minutes

y_0 = coliform bacteria density at time zero

y = coliform bacteria density at time t

This equation was used as the basis for the analysis of chlorination requirements during CR. Because it is impossible to accurately predict the chlorine demand, it was assumed to be proportional to the chlorine residual so that the chlorine dose applied to the wastewater will increase proportionately with the increasing chlorine residual predicted from Equation 3.

Equation 3 indicates that to maintain the same level of coliform reduction, the product of the chlorine residual (which is proportional to the dose) and the contact time must be a constant. Because the contact time is determined by dividing the volume of the chlorine contact tank by the average plant flow, for any given size tank the change in chlorine consumption can be related directly to the change in flow. Knowing the

pre-CR average daily chlorine consumption (from plant records) and average plant flow, the plant operator can use Equation 3 to estimate the increased chlorine consumption required for the estimated CR flow.

If contact tank storage is available for a long contact time, the amount of Cl_2 required can be much less than if limited storage is available. When limited storage is available, the plant operator must consider methods to insure sufficient kill by increasing the contact time. Some methods for accomplishing this are as follows:

1. Rapid dispersement of Cl_2 at the additional point to increase Cl_2 contact.
2. Baffles could be installed in the contact chamber to create turbulence and increase mixing.
3. Mechanical mixing or air agitation where plant hydraulics will not allow for the use of baffles.
4. A portion of the chamber could be converted to a mixing chamber and the remainder of the basin and/or outfall could serve for needed contact time.
5. Prior to CR, the contact chamber should be cleaned to reduce the solids buildup.

If the available chlorine supply is less than what is required to maintain the current levels of disinfection, then the plant operator should determine a daily consumption rate that would extend the supply of chlorine for the estimated duration of CR. This will result in some decrease in disinfection efficiency, but will be preferable to exhausting the supply of chlorine during the later stages of CR. However, before this alternative is pursued, local health and water quality regulatory personnel should be contacted, particularly if downstream uses of the receiving water include human contact or consumption.

METHODS FOR OVERALL REDUCTION OF TREATMENT PLANT LOADS

During CR, many treatment plants will not be able to effectively process the entire load coming into the plant. If the results of the worksheets in the manual indicate that a hydraulic, organic, and/or solids overloading may cause severe problems during CR, an alternative to processing the entire CR load at a reduced level of treatment is to reduce the load coming into the plant.

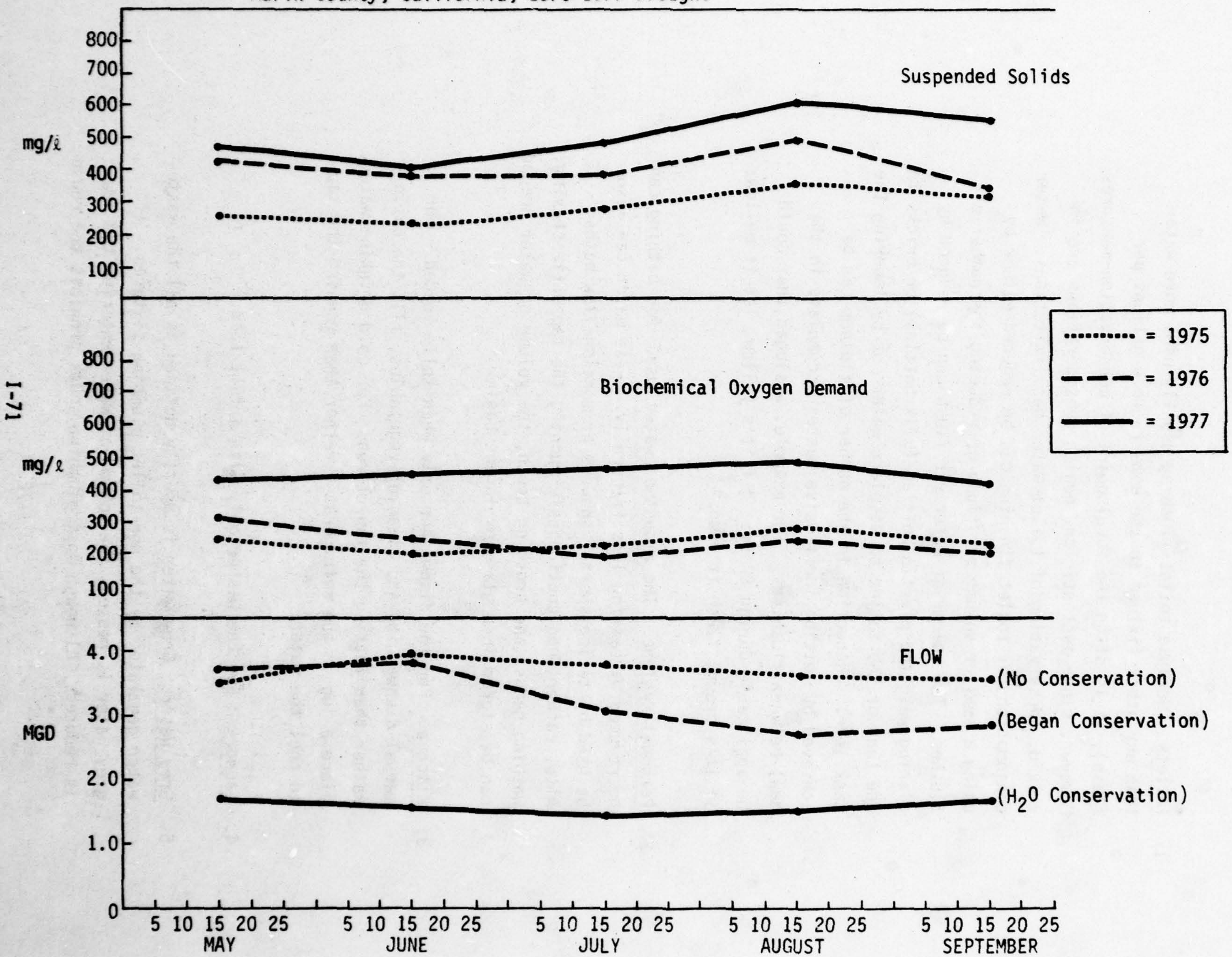
Loads on a treatment plant can be reduced either by decreasing or eliminating wastes entering the collection system or by diverting part of the collected waste around the treatment plant by an intentional or unintentional bypass. Some of the methods of controlling wastes entering the collection system are: water conservation, flow equalization, temporary industry shutdowns, and provision for emergency facilities. A brief description of each of the above methods for load reduction is given in the manual. This discussion will elaborate on some of these methods.

Home/Congregate Care Center Water Conservation

The practice of water conservation measures in the home and congregate care centers can significantly reduce the hydraulic load on a sewage treatment plant. As an example, water conservation in San Rafael, California, during the 1976-1977 California drought resulted in a 50% reduction in sewage flow, demonstrating that the effect of conservation on the hydraulic load can be significant. Water conservation does not affect the solids or organic load so that the flow reduction causes a corresponding increase in the BOD and suspended solids concentration, as shown in Fig. I-19.

Water has multiple uses within the home or congregate care center and each use has its own methods of conservation to minimize the health hazard and inconvenience. Ways of instituting water conservation for some of these uses follow.

Fig. I-19. Effect of Water Conservation on Sewage Treatment Plant Effluent, San Rafael, Marin County, California, 1976-1977 Drought



1. Toilets. Because toilet flushing usually uses more water than any other fixture in the home (5 to 6 gallons per flush), it is often the focal point of conservation measures. However, since aesthetic and health considerations are involved, conservation of toilet water has limitations. Water consumption for toilet flushing can be reduced either by using a smaller volume per flush or reducing the number of flushes. The volume of water per flush can be reduced by placing weighted plastic bottles (milk bottles) or bricks in the tank of the toilet to displace water or by lowering the tank level. Reduction in the number of flushes can be achieved by letting inoffensive wastes accumulate in the bowl between flushings. For example, a slogan that could be applicable during CR is: "If it's yellow, let it mellow; if it's brown, flush it down."

2. Personal Hygiene. The amount of water used for bathing can be reduced by bathing less frequently. Less water can also be used by taking shorter showers or more shallow baths. Also, rather than continuously running the tap while shaving, washing hands, and brushing teeth, the volume of water needed can be stored in a glass or in the basin.

3. Kitchen. Run the dishwasher only when fully loaded. For manual dishwashing and cleaning vegetables, fill the basin rather than letting the faucet run. For cold drinking water, place a jug in the refrigerator rather than running the tap to cool the water.

4. Laundry. Run the washer only with a full load.

5. Grey Water. Grey water is usually defined as all the wastewater generated by the non-toilet plumbing fixtures. If grey water is reused, the volume of water entering the sewer is reduced. Although most plumbing codes prohibit the reuse

of grey water, it can be safely reused if the proper precautions are taken. Some examples of safe grey water use are given in the two pamphlets by the California Department of Health (Ref. 25) and California Department of Water Resources (Ref. 26), and includes the following:

a. Collect shower water and with buckets use it to flush the toilet.

b. Disconnect basin drains and catch wastewater for toilet flushing or irrigation of plants.

c. Divert dishwasher and washer drain hoses into a garbage can for further use — toilet flushing or irrigation.

Flow Equalization

Flow equalization refers to methods designed specifically to dampen the normal diurnal flow variations in hydraulic, organic, and solids loadings. The benefits from flow equalization are numerous. It can reduce the peak overflow rates in settling basins, resulting in improved efficiency and possibly fewer disruptions from peak flows. Aerobic biological treatment processes can also benefit from the concentration damping and flow smoothing by eliminating peaks in organic load in excess of aeration capacity. Its major advantage is to protect sensitive treatment processes from failure due to shock loads and to improve overall process treatment efficiency.

During CR, flow equalization measures can take two forms: (1) measures directed at modifying the timing of the loads at the source, or (2) measures directed at modifying treatment plant operations. Measures directed at modifying the timing of the loads at the source depend on changing people's water-use habits and thus may be difficult to implement.

Fig. I-20 is illustrative of the hourly variation in home water use by type of water use, and demonstrates the wide variations that can occur. Plant flow records can be used to identify the peak hourly flow and then efforts can be directed at trying to encourage these uses at low-flow times of the day.

Temporary Industry Shutdowns

Industrial wastes are often major contributors to the hydraulic, organic, and solids loads handled by a wastewater treatment facility. Under severe overloading conditions, mutual arrangements could be made to temporarily shut down certain industries to reduce overloading problems. Thus, industrial contributions need to be inventoried prior to CR to assess the potential impact on the operations of the treatment plant.

For most host areas, it is anticipated that a comprehensive record of industrial waste discharges will be available from historical records of sewer charges. For example, the Ten-State Standards of the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers (Ref. 14) requires that engineers list all establishments producing industrial wastes and give quantity, producing periods, and the character of industrial wastes insofar as they may affect the sewerage system. Also, the federally funded PL 92-500 construction grants require that industry pay its "fair share;" thus, records of industrial contributions should be available in many CR host areas.

When existing records are not available to assess industrial waste contributions, it is recommended that a rapid industrial waste survey be conducted to determine the hydraulic, organic, and solids load for each industry. Hydraulic contributions may be obtained from past water consumption records, while the organic and solids load can be estimated from laboratory analysis from each source. The recommended laboratory tests to estimate the organic and solids loading are given in Table I-17 and include both rapid approximate tests and the more lengthy direct tests that

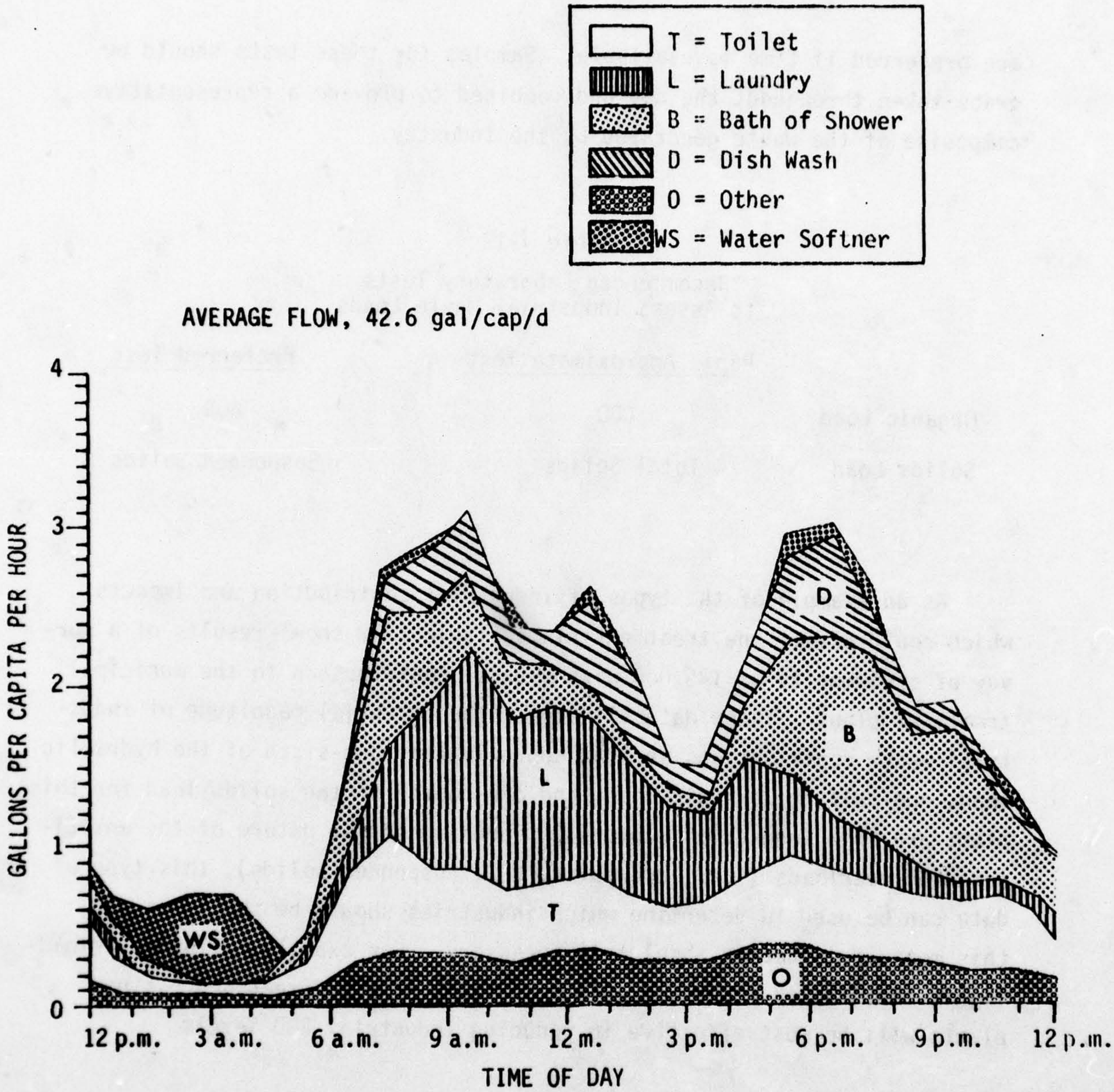


Fig. I-20. Average Daily Flow Pattern from Eleven Rural Households in Wisconsin.

Source: Witt, M.D. (Ref. 27).

are preferred if time is available. Samples for these tests should be grabs taken throughout the day and combined to provide a representative composite of the waste generated by the industry.

Table I-17

Recommended Laboratory Tests to Assess Industrial Waste Loads

	Rapid Approximate Test	Preferred Test
Organic Load	COD	BOD
Solids Load	Total Solids	Suspended Solids

As an example of the types of industrial contribution and impacts which could affect the treatment plant, Table I-18 shows results of a survey of a community of 145,000 with several contributors to the municipal treatment plant. These data illustrate the potential magnitude of industrial waste contributions in that approximately one-sixth of the hydraulic load, one-half the organic load, and one-fourth of the solids load for this plant are from industrial sources. Depending on the nature of the anticipated CR overloads (i.e., hydraulic, BOD, suspended solids), this type of data can be used to determine which industries should be shut down, if this measure is deemed absolutely necessary. For example, if BOD overloading is anticipated to be a problem, shutting down the meat processing plants will be most effective in reducing industrial BOD levels.

Table I-18

Results from a Municipal Industrial Waste Survey Listing Discharges to the Sanitary Sewer in a City with a Population of 145,000

	Flow (GPD)	% Total*	(Lb/day)	% Total*	(Lb/day)	% Total*
Meat processing	1,200,000	6.9	13,000	28.1	9,600	20.1
Soybean oil extraction	478,000	.3	880	1.9	560	1.2
Rubber products	189,000	1.1	310	.7	390	.8
Ice cream	138,000	.8	1,050	2.3	300	.6
Cheese	110,000	.6	2,900	6.3	890	1.9
Metal plating	108,000	.6	7	.01	24	.05
Carpet mill	103,000	.6	120	.3	51	.1
Candy	97,700	.6	1,270	2.7	210	.4
Motor scooters	93,500	.5	23	.05	20	.04
Potato chips	90,400	.5	450	1.0	510	1.1
Flour	83,100	.5	230	.5	250	.5
Milk processing	65,100	.4	760	1.6	170	.4
Industrial laundry	50,000	.2	290	.6	190	.4
Pharmaceuticals	40,700	.2	91	.2	50	.1
Chicken hatchery	35,300	.2	59	.1	90	.2
Luncheon meats	20,900	.1	47	.1	10	.02
Soft drinks	16,000	.1	64	.1	64	.1
Milk bottling	12,700	.1	24	.05	12	.03
Total	2,930,000	14.3	21,600	46.6	13,400	28.04

*Assumes domestic contribution from 145,000 population of .17 lb BOD/capita/day, .15 lb solids/capita/day, and 100 gpd.

Source: Hammer (Ref. 28).

Section 3

MANUAL TESTING AND EVALUATION

The initial testing of the manual took place at four local San Francisco Bay area plants. The sites were chosen so that at least one of each of the major types of treatment plants (i.e., trickling filter, activated sludge, and aerated lagoon) was visited. To simulate CR conditions, the current population served by each plant was tripled. The data from these visits, as compiled on the following summary sheets, indicated a variety of potential problems at the different plants.

All of the plants were found to have an adequate supply of chlorine for disinfection. Because of the demand for chlorine due to the increased BOD and hydraulic loads, supplies ranged from less than 1 day to a maximum of 3.4 days, while maintaining the current levels of disinfection. In each case, the amount of chlorine necessary to provide a current level of disinfection during the CR period would create storage and handling problems even if it were available.

The analysis of the trickling filter plants at Redwood City and San Carlos (see Tables I-19 and I-20, respectively) indicated excessive hydraulic overflow rates in the primary and secondary clarifiers. The projected increase in the BOD loads to both plants initially indicated a complete loss of treatment in the trickling filters. This was particularly a problem at the San Carlos plant where the trickling filter was found to be currently operating at about 29% efficiency and the secondary clarifier overflow rate already exceeded the recommended maximum of 1,200 gpd/sq ft. A minor modification of the trickling filter analysis was made based on the problems encountered at these plants. The analysis now provides for a more realistic decrease in treatment efficiency based on the organic loading increases to

Table I-19

Trickling Filter Plant at Redwood City

SUMMARY SHEET OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

PROCESS →		PRIMARY	TRICKLING FILTER		ACTIVATED SLUDGE			ANAEROBIC DIGESTION	P O N D S		L A G O O N S		CHLORINATION	
PARAMETER →		HYDRAULIC OVERFLOW RATE	ORGANIC LOADING	CLARIFIER OVERFLOW RATE	EXCESS AERATION CAPACITY	F/M RATIO	CLARIFIER OVERFLOW RATE	HYDRAULIC DETENTION TIME	DETENTION TIME	BOD LOAD	DETENTION TIME	EXCESS AERATION CAPACITY	CONTACT TIME	Cl_2 SUPPLY
CALCULATED VALUE →		2,570	566	573 802	X	X	X	18.2 days	X	X	X	X	1.8 min.	2.4 days
Worksheet Line :		22B	32E	34C & D	47F & G	46	48A & B	70B	55E	55C	55E	58F	82D	82C
GENERALIZED EFFECTS: FAILURE	1*						> 1200	< 7 days					< 5 min.	< 5 days
GENERALIZED EFFECTS: POSSIBLE FAILURE	2*				< 0	> 0.5 Bulking	> 800	> 7 days < 12 days (stressed)					< 10 min	< projected CR duration
GENERALIZED EFFECTS: DECREASED TREATMENT	3*	~1200	gradual (see work-sheet)	>1200	approaching zero				gradual (see work-sheet)	gradual (see work-sheet)	gradual (see work-sheet)	approaching zero	< 15 min	< 60 days
GENERALIZED EFFECTS: NUISANCE	4*		odors increased values		possible odors					odors at higher loads		odors at < 0		

NOTE: An empty box denotes no significant problems.

* ACTIONS RECOMMENDED DEPENDING ON THE SEVERITY OF THE GENERALIZED EFFECT:

1. AVOID AT ALL COSTS 2. INTENSIVE CONTROL 3. CONSULT REGULATORY AGENCY 4. IGNORE

Table I-20

Trickling Filter Plant at San Carlos

SUMMARY SHEET OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

PROCESS →		PRIMARY	TRICKLING FILTER		ACTIVATED SLUDGE			ANAEROBIC DIGESTION	P O N D S		L A G O O N S		CHLORINATION	
PARAMETER →		HYDRAULIC OVERFLOW RATE	ORGANIC LOADING	CLARIFIER OVERFLOW RATE	EXCESS AERATION CAPACITY	F/M RATIO	CLARIFIER OVERFLOW RATE	HYDRAULIC DETENTION TIME	DETENTION TIME	BOD LOAD	DETENTION TIME	EXCESS AERATION CAPACITY	CONTACT TIME	Cl_2 SUPPLY
CALCULATED VALUE →		3,407	449	3,406 Av. 6,813 Pk.	X	X	X	37 days	X	X	X	X	55 min.	less than 1 day
Worksheet Line		22B	32E	34C & D	47F & G	46	48A & B	70B	55E	55C	55E	58F	82D	82C
GENERALIZED EFFECTS — FAILURE	1*						> 1200	< 7 days					< 5 min.	< 5 days
POSSIBLE FAILURE	2*				< 0	> 0.5 Bulking	> 800	> 7 days < 12 days (stressed)					< 10 min	< projected CR duration
DECREASED TREATMENT	3*	>1200	gradual (see work-sheet)	>1200	approaching zero				gradual (see work-sheet)	gradual (see work-sheet)	gradual (see work-sheet)	approaching zero	< 15 min	< 60 days
NUISANCE	4*		odors increased values		possible odors					odors at higher loads		odors at <0		

NOTE: An empty box denotes no significant problems.

* ACTIONS RECOMMENDED DEPENDING ON THE SEVERITY OF THE GENERALIZED EFFECT:

1. AVOID AT ALL COSTS 2. INTENSIVE CONTROL 3. CONSULT REGULATORY AGENCY 4. IGNORE

the filter and takes into account the somewhat extreme increases in loading that might occur during CR.

The activated sludge plant in San Rafael (Table I-21) would experience potential hydraulic overloads in both the primary and secondary clarifiers when subjected to a 3 to 1 increase in population. It was also found that only about half of the capacity of the first stage digester was available for actual digestion because of an excessive accumulation of grit in the tank. This resulted in a detention time of only 1.7 days for the total sludge production and about 6 days if only primary sludge was treated. Significant increases in detention time would occur if the digester could be cleaned prior to CR indicating that all of the primary sludge and at least some of the secondary sludge could be treated.

The aerated lagoon facility at Menlo Park (Table I-22) exhibited the fewest problems of the plants visited. This is due in part to the plant being currently overdesigned thus allowing for some increase in population without exceeding the design capacity of the plant. In addition, lagoons are generally less sensitive to hydraulic and organic overloads because of their size. With the projected 3 to 1 population increase it was found that the mechanical aerators were inadequate for the organic load, but this deficiency would probably result in only a relatively minor decrease in effluent quality.

Generally, there were no problems experienced in obtaining the operational data necessary to complete the worksheets. The Redwood City plant did not keep their laboratory test records at the plant and thus had to consult with their central office to obtain these data. This resulted in only a slight delay and did not prove to be a great difficulty. It was pointed out that in the event that such records were unavailable at the local level, representative operating data should be available from state regulatory agencies.

Table I-21

Activated Sludge Plant at San Rafael

SUMMARY SHEET OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

PROCESS →		PRIMARY	TRICKLING FILTER		ACTIVATED SLUDGE			ANAEROBIC DIGESTION	PONDS		LAGOONS		CHLORINATION	
PARAMETER →		HYDRAULIC OVERFLOW RATE	ORGANIC LOADING	CLARIFIER OVERFLOW RATE	EXCESS AERATION CAPACITY	F/M RATIO	CLARIFIER OVERFLOW RATE	HYDRAULIC DETENTION TIME	DETENTION TIME	BOD LOAD	DETENTION TIME	EXCESS AERATION CAPACITY	CONTACT TIME	Cl_2 SUPPLY
CALCULATED VALUE →		1,586	X	X	2,896 Av. 1,401 Pk.	0.1	953 Av. 1,109 Pk.	1.7 total	X	X	X	X	31 min.	3.4 days
Worksheet Line:		22B	32E	34C & D	47F & G	46	48A & B	70B	55E	55C	55E	58F	82D	82C
GENERALIZED EFFECTS: FAILURE	1*						> 1200	< 7 days					< 5 min.	< 5 days
GENERALIZED EFFECTS: POSSIBLE FAILURE	2*				< 0	> 0.5 Bulking	> 800	> 7 days < 12 days (stressed)					< 10 min	< projected CR duration
GENERALIZED EFFECTS: DECREASED TREATMENT	3*	>1200	gradual (see work-sheet)	>1200	approaching zero				gradual (see work-sheet)	gradual (see work-sheet)	gradual (see work-sheet)	approaching zero	< 15 min	< 60 days
GENERALIZED EFFECTS: NUISANCE	4*		odors increased values		possible odors					odors at higher loads		odors at < 0		

NOTE: An empty box denotes no significant problems.

* ACTIONS RECOMMENDED DEPENDING ON THE SEVERITY OF THE GENERALIZED EFFECT:

1. AVOID AT ALL COSTS 2. INTENSIVE CONTROL 3. CONSULT REGULATORY AGENCY 4. IGNORE

Table I-22

Aerated Lagoon Plant at Menlo Park

SUMMARY SHEET OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

PROCESS →		PRIMARY	TRICKLING FILTER		ACTIVATED SLUDGE			ANAEROBIC DIGESTION	PONDS		LAGOONS		CHLORINATION	
PARAMETER →		HYDRAULIC OVERFLOW RATE	ORGANIC LOADING	CLARIFIER OVERFLOW RATE	EXCESS AERATION CAPACITY	F/M RATIO	CLARIFIER OVERFLOW RATE	HYDRAULIC DETENTION TIME	DETENTION TIME	BOD LOAD	DETENTION TIME	EXCESS AERATION CAPACITY	CONTACT TIME	Cl_2 SUPPLY
CALCULATED VALUE →		833	X	X	X	X	X	24 days	X	X	5.8 days	Zero	Many Hours	Less Than 1 day
Worksheet Line :		22B	32E	34C & D	47F & G	46	48A & B	70B	55E	55C	55E	58F	82D	82C
GENERALIZED EFFECTS: FAILURE	1*						> 1200	< 7 days					< 5 min.	< 5 days
GENERALIZED EFFECTS: POSSIBLE FAILURE	2*				< 0	> 0.5 Bulking	> 800	> 7 days < 12 days (stressed)					< 10 min	< projected CR duration
GENERALIZED EFFECTS: DECREASED TREATMENT	3*	>1200	gradual (see worksheet)	>1200	approaching zero				gradual (see worksheet)	gradual (see worksheet)	gradual (see worksheet)	approaching zero	< 15 min	< 60 days
GENERALIZED EFFECTS: NUISANCE	4*		odors increased values		possible odors					odors at higher loads		odors at < 0		

NOTE: An empty box denotes no significant problems.

* ACTIONS RECOMMENDED DEPENDING ON THE SEVERITY OF THE GENERALIZED EFFECT:

1. AVOID AT ALL COSTS 2. INTENSIVE CONTROL 3. CONSULT REGULATORY AGENCY 4. IGNORE

AD-A063 713 SCIENTIFIC SERVICE INC REDWOOD CITY CA F/G 15/3
EMERGENCY SEWAGE PROCEDURES DURING CRISIS RELOCATION.(U)
NOV 78 R FISHER, L DICKINSON, J MEYER DCPA01-77-C-0230
UNCLASSIFIED SSI-7728-4 NL

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The manual was distributed to three operators of treatment plants in the Canon City, Colorado area. SSI personnel met with these operators and with Civil Defense officials in Canon City on September 30, 1978 to discuss the manual. The general consensus of the operators was that they found the manual easy to follow and they could suggest no additions nor deletions.

Section 4
OTHER ISSUES

This section will briefly discuss two other issues pertinent to the subject of this report but which are not conveniently included under the preceding report sections. These two issues are: (1) the environmental impacts of sewage treatment plant operations during CR, and (2) new construction modifications.

ENVIRONMENTAL IMPACTS

This section briefly discusses the potential environmental impacts of the operation of sewage treatment plants during CR. Impacts can be categorized according to whether their effects are positive or negative and whether they are short term or long term. Since the purpose of the manual is to help plant operators minimize the environmental impacts of their plants during CR (i.e., actions with positive impacts), this section will deal only with the negative impacts. Short-term impacts are assumed to be any impact that occurs during CR or up to 1 to 2 months thereafter. Long-term impacts (called legacy impacts) are assumed to last for 6 months or more.

Most of the impacts associated with the operation of sewage treatment plants during CR will probably be short term. The following is a brief discussion of the most significant short-term impacts:

1. <u>Disposal of Sludge</u>. Depending on the degree of stabilization and treatment provided during CR, the disposal of the additional CR solids in sanitary landfills or by land application methods could cause public health problems if surviving

pathogens are allowed to contaminate drinking water supplies. Thus care must be taken to ensure that the sludge is properly dewatered, or alternately, the leachate and runoff from the landfill should be collected and treated.

2. Decreased Effluent Quality. The impacts of decreased effluent quality are site-specific and their magnitude depends on many factors including the time of the year, the magnitude and nature of the decreased effluent quality, the downstream use of the receiving waters, etc. If the receiving water is ultimately consumed and the pathogen standard is exceeded, then potential public health problems could occur. If the BOD load is increased it could decrease the oxygen level in the receiving waters to the extent that it could either stress or even be lethal to some fauna.

3. Toxic Effects of Chlorine. Chlorine can be toxic to certain freshwater organisms, especially certain cold water fish, such as trout, salmon, and fish-food organisms. Basch and Truchan (Ref. 29) recommend maximum concentrations of 0.02 and 0.005 mg/ℓ for warm water and cold water fish, respectively. However, if no pre-CR chlorine toxicity problems exist, then the possibility of CR toxicity problems is remote unless for some reason the CR effluent chlorine concentration is increased. This is very remote since chlorine will probably be in short supply during CR.

4. Exfiltration from Sewer Lines. The increased hydraulic flow during CR could cause some sewage to seep out from the joints and cracks in the sewer pipes. The magnitude of this impact will probably be small and will depend on the location and amount of seepage in relation to nearby drinking water supplies.

5. <u>Temporary Construction Impacts</u>. Any temporary construction such as bypasses, ponds or lagoons, overflow containments, etc. will involve all the impacts associated with construction projects such as construction equipment noise, air pollution, soil erosion, etc.

6. <u>Septic Tank Failure</u>. Failure of a septic tank system occurs when the drain field can no longer assimilate the waste flow. The environmental consequences of such a failure vary with the situation. The usual symptoms are contamination of surrounding wells or surfacing of odorous effluent. Each drain field has some finite hydraulic capacity which could be exceeded during CR. Quantification and prediction of this capacity is difficult because the wide local variations in soil type in any geographic area can strongly influence this capacity. One effect of increased hydraulic flow on drain field capacity is that continuous inundation of the soil will, even with clear water, eventually clog the soil. Thus, the longer relocation continues, the greater the chance for septic tank failure.

The potential long-term impacts of the operation of sewage treatment plants during CR are few. They could include any of the following:

1. <u>Disposal of Solids</u>. Land which was utilized as a sludge disposal site should not be used for at least 1 year for the production of human food crops normally eaten raw. This will ensure that any pathogens surviving the sludge treatment process will be destroyed by various environmental factors.

2. <u>Decreased Effluent Quality</u>. If the magnitude and conditions associated with the decreased effluent quality are

lethal enough such that a particular species of fauna is killed in a localized area, then the ecological niche filled by that species will be replaced by another according to the principles of ecological succession. This process may or may not upset the localized ecological balance but in any case will be a long-term change.

CONSTRUCTION MODIFICATION

One task under this program was to determine modifications which could be installed during construction of new or renovation of old plants which could significantly upgrade their capability for handling increased loadings.

During the development and testing phases of the manual it became clear that, aside from oversizing the entire plant and minor changes like enlarging the effluent handling equipment (which could only be determined on a plant-by-plant basis*), there were only three significant modifications that could increase the capacity of any plant. These are: installation of a bypass; provision for emergency storage and treatment; and increased chlorine inventory. Each of these will be discussed in detail below.

Bypass

To bypass a portion of the effluent, with or without partial treatment, is standard operating procedure in many areas of the country, particularly during the rainy season or in plants of marginal capacity. This procedure is illegal in many states (including California) and typically violates EPA effluent regulations.

It may under certain conditions, i.e., to prevent failure of the entire plant, be necessary to bypass a portion of the effluent during CR. This

*This analysis could be performed using the worksheets in the manual.

should be done with considerable care, however, to prevent contamination of water supplies, spread of disease, etc. In all cases the bypassed effluent should be partially treated (disinfected with chlorine, for example).

Emergency Storage and Treatment

The most practical and economical facility for emergency storage and treatment of effluent is a pond or lagoon. These are large earthen basins used to retain wastewater and allow biological treatment to take place. A lagoon is usually defined as a retention basin which uses artificial aeration and a pond — whether aerobic, facultative, or anaerobic — usually relies on natural aeration. Ponds or lagoons are relatively simple to construct and if sufficient land is available could be added during construction or renovation at very little increased cost.

Chlorine

As noted many times in this report and in the manual, CR will require increased use of chlorine. In conversation with operators there is a reluctance to store more than a few days to a week's normal supply. One reason is the hazard associated with this volatile chemical and the second is the cost associated with the demurrage charges for chlorine cylinders. This suggests that the following be done: an increased storage capability should be provided, backed up by a pre-CR plan to move chlorine to the host area. Minor plant modifications should be explored which would allow use during CR of the larger containers — trucks, railroad cars, and the like — commonly used for transportation.

None of these modifications is cost intensive and would probably not increase the cost of construction more than 2% to 5%. There is the additional modification which should also be discussed, however, that of emergency power. The assumption has been throughout most of the manual that electric power would be available. In case of attack, however, this may not be the case and provision for emergency power either within the plant or from an outside source should be made.

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32. California State Water Resources Control Board, Rural Wastewater Disposal Alternatives, Final Report - Phase I, September 1977.

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34. Mann, H.T., Water Treatment and Sanitation, 1976.

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in = 3.28 ft = 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	μm.		3.937 X 10^{-3} = 10^{3}A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or megagram	t Mg	1 tonne = 1 000 kg 1 Mg = 1 000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N·m	The metre is measured perpendicular to the line of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2 120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa·s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	
	degree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	$\frac{5F}{9} - 17.77$
Work, energy, quantity of heat	joule	J	1 joule = 1 N·m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/l		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^{3}d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^{2}d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^{3}d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	lumen/m^2		0.092 ft candle/sq ft

7728-4 November 1978

EMERGENCY SEWAGE PROCEDURES

DURING

CRISIS RELOCATION

Part II - Manual

prepared for

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Washington, D.C.

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Work Unit 2422E

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Table of Worksheets

List of Acronyms and Abbreviations

BA	bicarbonate alkalinity
BOD	biochemical oxygen demand
CR	crisis relocation
DCPA	Defense Civil Preparedness Agency
DO	dissolved oxygen
DOB	depth of blanket
EPA	U.S. Environmental Protection Agency
F/M	food to micro-organism ratio
gpd	gallons per day
Jtu	Jackson turbidity unit
MG	million gallons
mgd	million gallons per day
mg/l	milligrams per liter
MLSS	mixed liquor suspended solids
MVLSS	mixed liquor volatile suspended solids
MPN	most probable number
SS	suspended solids
SVI	sludge volume index
TA	total alkalinity
VA	volatile acids

INTRODUCTION

CRISIS RELOCATION PLANNING

Crisis Relocation Planning is a comprehensive effort by the Defense Civil Preparedness Agency to prepare contingency plans for the relocation of population from high-risk areas to protect them from the combined blast and radiation effects of nuclear weapons. This concept assumes that a nuclear attack on the United States would be preceded by a crisis buildup phase allowing sufficient time for protective action to be taken, such as the relocation of residents from possible target areas to areas of low risk, and the preparation of facilities and services for taking care of the relocated population in the host areas. The relocation time will be very short, i.e., probably a few days. While this short period does allow sufficient time for relocation and some preparation for providing services and protection for the relocated population, it most certainly does not allow time for planning. Thus, all necessary planning for the various operating and support functions must be completed prior to the crisis period. One important support function is sewage treatment. An adequate sewage treatment system is absolutely essential during CR* for the protection of the health of the relocatees and the prevention of spread of communicable diseases. Of particular concern is the contamination of water supplies.

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* Throughout this manual, the crisis relocation period will be expeditiously referred to as CR. Similarly, pre-CR is used to refer to normal operations prior to CR.

OBJECTIVES OF THIS MANUAL

This manual is designed with two objectives in mind. One objective is to provide a set of guidelines with which a host area sewage treatment facility engineer/operator can estimate the impact and determine how to cope with the added load caused by an increased population associated with CR. The other objective is to provide DCPA personnel with an approach for predicting how their CR plans will impact sewage treatment plant operations and how and when sewage treatment plant capacities may be a factor limiting the maximum number of relocatees that a particular host area can support.

APPLICATION OF MANUAL TO ACTUAL TREATMENT PLANTS

A review of Environmental Protection Agency data inventorying sewage treatment facilities in the United States indicates that the sewage treatment facilities in small towns can be categorized as primary treatment, trickling filters, ponds, aerated lagoons, and activated sludge. Thus, this manual concentrates on these processes. Fig. II-1 represents a "typical" generalized sewage treatment plant that might be found in a "typical" CR host community. This "typical" treatment plant has the following generalized characteristics. Raw wastewater first undergoes pre-treatment consisting of screening, grit removal, flow measurements, and possibly pre-aeration. After pre-treatment, the wastewater usually is subjected to primary treatment consisting of suspended solids removal by sedimentation. The effluent from primary clarification is usually given biological treatment, chlorinated and discharged or simply chlorinated and discharged. Sludge solids are subjected to some type of biological treatment, de-watered, and removed to a disposal area.

Obviously any particular plant may be somewhat different from the generalized scheme since there are an infinite number of ways of combining the basic processes into a properly functioning sewage treatment plant.

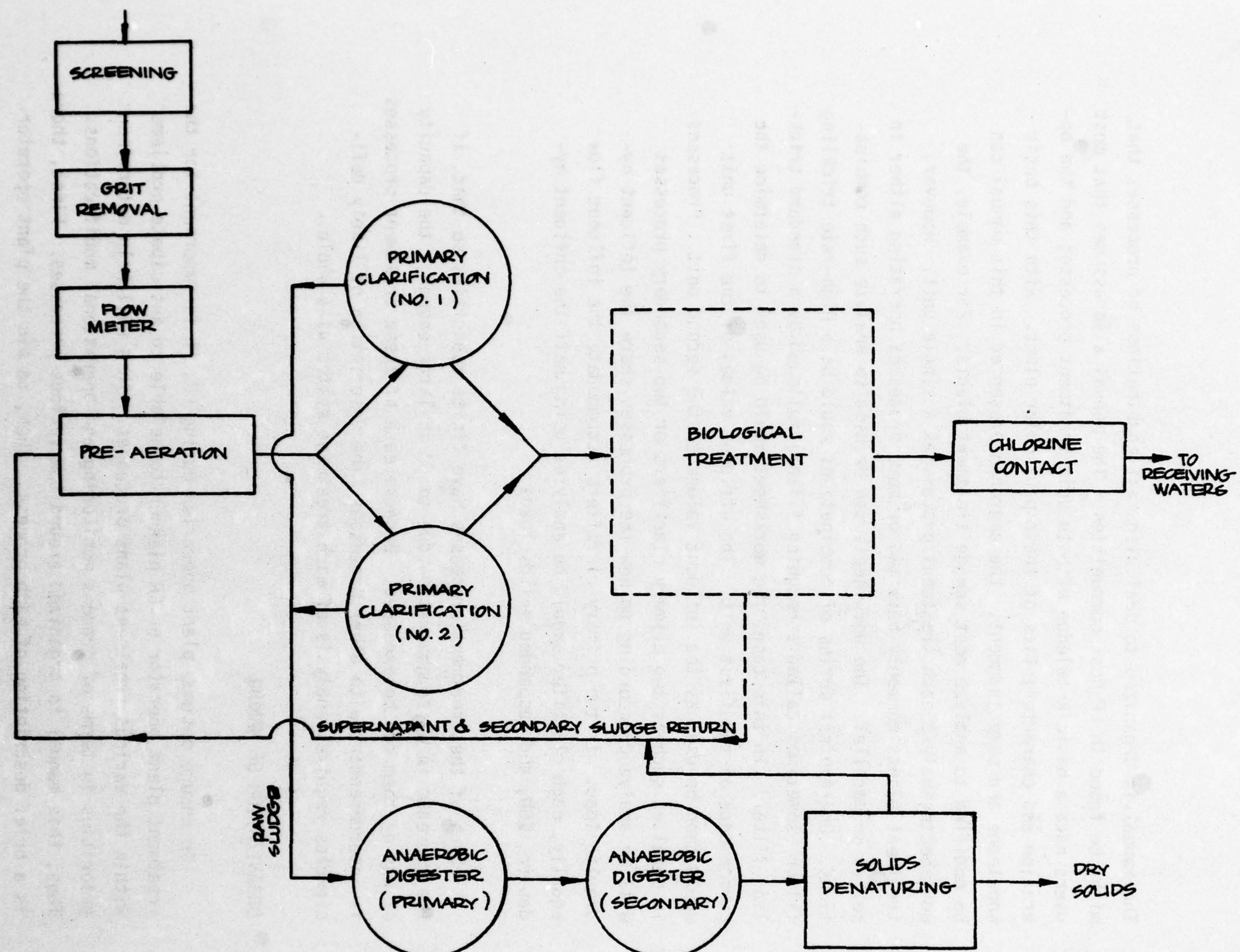


Fig. II-1 "Typical" Generalized Sewage Treatment Plant.

The manual is organized to deal with most combinations of processes that might be found in CR host communities. The manual also assumes that most users have a basic knowledge of both unit treatment processes and the operation and characteristics of their particular plant. With this basic knowledge and some judgment, the approach presented in this manual can be modified to analyze most sewage treatment plants. For example, the worksheets analyze each treatment process as a single unit. However, treatment plants commonly have two or more processes operating either in series or parallel. The worksheets can be used to analyze such combinations. One typical series of combinations would be a high-rate trickling filter (sometimes called a roughing filter) followed by a standard trickling filter. In this case, the worksheet would be used to determine the performance of the first unit. The effluent values of the first unit would then be used as the influent values to the second unit. Processes in parallel such as two primary clarifiers or two secondary processes will be analyzed according to how the processes share the influent hydraulic load. If two primary clarifiers accommodate the influent flow equally, each clarifier should be analyzed using half the influent hydaulic, BOD, and suspended solids loads.

Each of the treatment processes have finite capacities so that, if the increase in waste generation due to CR is large enough, the capacity of any of them can be exceeded. Because each of these treatment processes is interdependent with other processes, the description of likely deficiencies requires analysis of each treatment system as a whole.

ORGANIZATION OF MANUAL

To ensure optimum plant operation during CR, it is important for the treatment plant operator or CR planner to be able to anticipate problems within the various treatment plant processes. This will help determine priorities in terms of process monitoring and operational modifications. Thus, this manual is organized around the various processes. First, there is a brief description of each process. Then, to aid the plant operator

or CR planner, worksheets have been set up to detail each individual calculation that is needed to estimate performance of the different processes and identify trouble areas within the plant. A brief worksheet description precedes each worksheet. The worksheets are arranged to provide a step-by-step analysis of present operating conditions, the projected operational loadings during CR, and the effect of these increased loadings on process operations. Following each worksheet there is a discussion of operational problems likely to occur during CR, followed by a detailed troubleshooting guide and brief discussion of laboratory tests that will be most useful in analyzing potential problems associated with CR.

Following the sections on treatment processes, a summary worksheet is provided which helps the user categorize the severity of potential problems associated with each process for a particular plant. The next section describes a variety of load reduction measures which can be implemented depending on the nature of the anticipated problem. The manual concludes with some sample forms dealing with various logistical arrangements pertinent to CR.

INSTRUCTIONS ON USE OF THIS MANUAL

For each worksheet, each individual calculation and its answer are indexed by a number and letter which allows easy cross-reference to related calculations and sections within the manual. (Note: the line item numbers are not consecutive.) The Table of Worksheets (page v) lists all the worksheets, the line numbers of each calculation contained therein, and the page numbers of the worksheet. The calculations on each line of the worksheets are set up in the order that they would be performed using a hand calculator. Only where there would be possible ambiguity as to the correct calculation sequence to be performed is standard algebraic notation using parenthesis provided. A word of caution is in order wherever percentages are encountered on the worksheets. Numerical values expressed as a percentage should not be converted to a decimal; where this is necessary, the appropriate conversion is incorporated into the computation.

Because of the wide variation in the treatment efficiencies experienced for a given process throughout the U.S., the calculations in the worksheets were developed to reflect the operations of a "typical" plant. The worksheets will be most appropriate for those plants that are "normal" in their pre-CR design and operation. Applying the worksheets to plants with unusually low pre-CR treatment efficiencies may result in some inconsistencies in the worksheet calculation results.

Regarding the laboratory/process control test sections of this manual, it is assumed that the users of this manual will have access either to a state laboratory wastewater test manual or to Standard Methods for the Examination of Water and Wastewater, 14th edition, American Public Health Association. Thus, no detailed descriptions are provided of the laboratory tests mentioned in this manual.

The following "road map" is provided as a brief illustration of how this manual can be used. The pre-CR and CR loading worksheet is completed first; this compiles the basic data on hydraulic flows, suspended solids, and organic BOD loads which are inputs to the other worksheets. Then, depending on the design and operation of a particular plant, select and complete the applicable process worksheets. For example, if the plant is a "typical" trickling filter plant, complete the following worksheets in this sequence: Primary Clarifier, Trickling Filter, Solids Handling, Anaerobic Digestion, and Chlorination. Following this, using the information in the various process worksheets, complete the Summary Sheet of Critical Process Values, Their Generalized Effects, and Actions Recommended. This summary sheet is designed to provide the operator, or CR planner, with a generalized hierarchy of problems so that priorities can be established in allocating scarce resources to the solution of the most critical problems. If the summary sheet indicates a process failure or potential failure, then load reduction measures need to be investigated. Ways of accomplishing this are reduction of the population contributing to the plant,

the elimination of non-essential waste contributors, and water rationing.

The next section explores the first option and is primarily for CRP planners. It is designed to show how the worksheets can be modified to estimate the maximum CR population based on the treatment plant capabilities. If a process failure is indicated during CR, then the next section on load reduction methods describes various alternatives for accomplishing this including bypasses, water conservation measures, flow equalization, temporary industry shutdowns, and emergency facilities. Depending on the nature of the overload problem (e.g., hydraulic or organic load) the appropriate load reduction measures should be explored. The last section contains some sample forms dealing with CR logistical arrangements which should be compiled prior to CR.

PRE-CR AND CR LOADING CONDITIONS

Crisis Relocation involves relocating the population from high-risk urban areas to less densely populated host areas. The magnitude of this relocation for any particular host area is currently being determined by DCPA. Whatever the magnitude of the relocated population, the relocatees will generate an increased load on the host sewage treatment plant in the form of hydraulic flows, suspended solids, and organic BOD loadings. To assess the effects of this increased population on the operation of the host sewage treatment plant requires a knowledge of both the pre-CR and CR loading characteristics.

The following worksheet is used to compile and tabulate the basic data on both pre-CR and CR treatment plant loading conditions; these data will be used frequently throughout the manual as inputs to the various treatment process worksheets. The required data include hydraulic flows, suspended solids loadings, and organic BOD loadings. Plant records should be able to provide hydraulic flow values for average dry weather flow and peak dry weather flow, and historical records of laboratory analyses of influent and effluent wastewater should provide concentrations of organic BOD and suspended solids. In the rare event that these data are unavailable from plant records, laboratory analyses will be required to obtain an estimate of these loadings.

WORKSHEET

Pre-CR Loading Conditions

Line		Quantity	Units	Line
1.	Pre-CR population served by treatment plant =	______	persons	1
2.	Hydraulic Flow			
A.	Average dry weather flow in mgd =	______	mgd	2A*
B.	Peak dry weather flow in mgd =	______	mgd	2B*
C.	Peaking Factor: (peak flow [2B]___mgd) ÷ (average flow [2A]___mgd) =	______	none	2C
3.	Suspended Solids			
A.	Average plant influent suspended solids concentration in mg/l =	______	mg/l	3A*
B.	Average plant effluent suspended solids concentration in mg/l =	______	mg/l	3B*
C.	Average number of pounds of suspended solids entering plant per day: (influent solids concentration [3A]___mg/l) x (average flow [2A]___mgd) x 8.34 lb/gal =	______	lb/day	3C
D.	Average number of pounds of suspended solids leaving plant per day: (effluent solids concentration [3B]___mg/l) x (average flow [2A]___mgd) x 8.34 lb/gal =	______	lb/day	3D
4.	Organic BOD			
A.	Average plant influent BOD concentration in mg/l =	______	mg/l	4A*
B.	Average plant effluent BOD concentration in mg/l =	______	mg/l	4B*
C.	Average number of pounds of BOD entering plant per day: (influent BOD concentration [4A]___mg/l) x (average flow [2A]___mgd) x 8.34 lb/gal =	______	lb/day	4C
D.	Average number of pounds of BOD leaving plant per day: (effluent BOD concentration [4B]___mg/l) x (average flow [2A]___mgd) x 8.34 lb/gal =	______	lb/day	4D
E.	Average number of pounds of BOD removed by plant per day: (BOD into plant [4C]_____lb/day) - (BOD out of plant [4D]___lb/day) =	______	lb/day	4E

* from plant records.

WORKSHEET

CR Loading Conditions

Line		Quantity	Units	Line
10 A.	Number of addition relocatees served by treatment plant =	______	persons	10A
B.	Total CR population: (pre-CR population [1] ______) + (relocatees [10A] ______)=	______	persons	10B
11.	Hydraulic Flow			
A.	Additional flow based on 50 gallons per day for each relocatee:			
	(relocatees [10A] ______) x (50 gal/person) ÷ (1,000,000) =	______	mgd	11A
B.	Average CR flow:			
	(average pre-CR flow [2A] ______ mgd) + (additional flow [11A] ______ mgd) =	______	mgd	11B
C	Peak CR flow:			
	(average CR flow [11B] ______ mgd) x (peaking factor [2C] ______) =	______	mgd	11C
12.	Suspended Solids			
A.	Additional pounds of suspended solids entering plant based on 0.08 pound of solids/person/day:			
	(relocatees [10A] ______) x (0.08 lb solids/person/day) =	______	lb/day	12A
B.	Average CR solids load to plant:			
	(average pre-CR solids load [3C] ______ lb/day) + (additional solids [12A] ______ lb/day)	______	lb/day	12B
C.	Peak CR solids load to plant:			
	(average CR solids load [12B] ______ lb/day) x (peaking factor [2C] ______) =	______	lb/day	12C
13.	Organic BOD			
A.	Additional pounds of BOD entering plant based on 0.1 pound of BOD/person/day:			
	(relocatees [10A] ______) x (0.1 lb BOD/person/day) =	______	lb/day	13A
B.	Average CR BOD load to plant:			
	(average pre-CR BOD load [4C] ______ lb/day) + (additional BOD [13A] ______ lb/day)=	______	lb/day	13B

WORKSHEET

CR Loading Conditions (contd)

Line		Quantity	Units	Line
13. C.	Peak CR BOD load to plant: (average CR BOD load [13B]________lb/day) x (peaking factor [2C]________) =	_______	lb/day	13C

PRIMARY SEDIMENTATION

PROCESS DESCRIPTION

Primary sedimentation or clarification consists of holding the wastewater in a large tank under quiescent conditions to remove suspended solids by settling under the influence of gravity. A primary clarifier provides the most economical method of removing approximately one third of the BOD and about two thirds of the suspended solids from domestic wastewater. The amount of BOD and suspended solids removed in the primary clarifier has a direct effect on the loads which must be handled by the other treatment processes; for this reason it is important to evaluate the treatment efficiency of the primary clarifier under CR conditions.

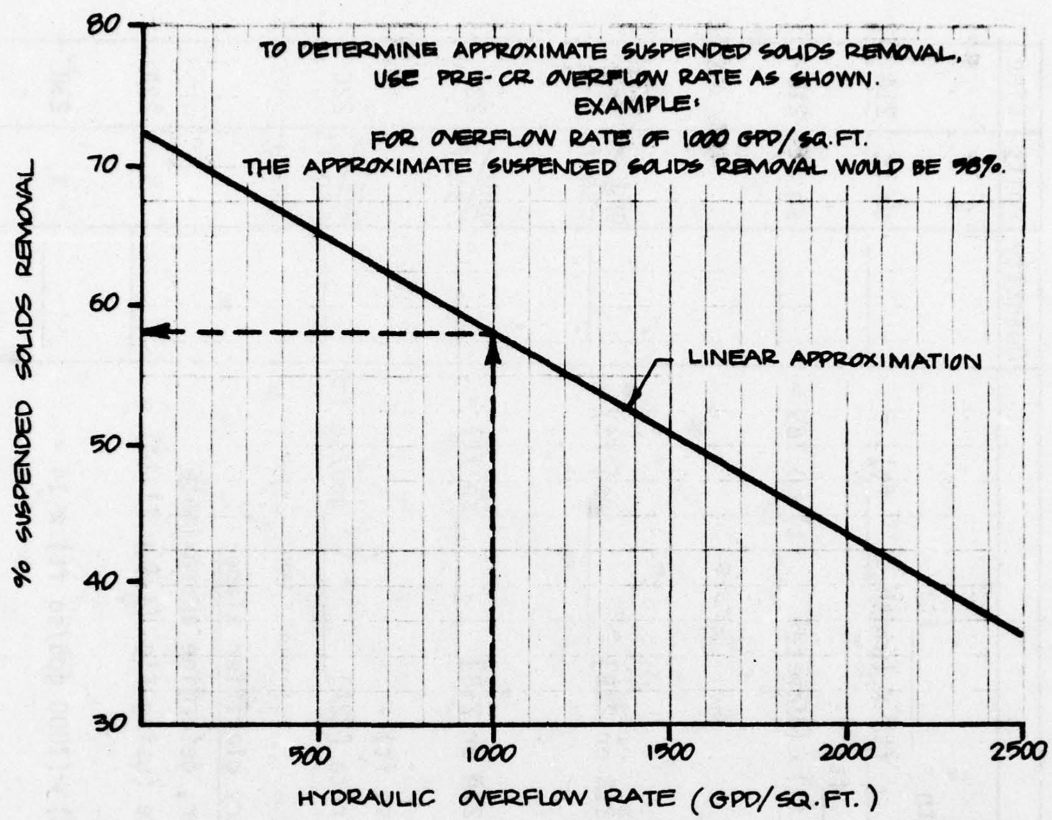
There are four main operating parameters associated with the primary clarifier: the hydraulic overflow rate; the hydraulic detention time; the weir overflow; and the horizontal velocity of the wastewater in the clarifier. The hydraulic overflow rate, however, is the major parameter that governs the efficiency of primary clarifiers for removing both suspended solids and BOD and therefore, it is the basis in the worksheet for evaluating clarifier performance.

The primary clarifier generally produces the greatest quantity of sludge solids of the various treatment processes, and thus will present a major solids handling problem during CR. Primary sludges consist of the organic matter responsible for the offensive character of untreated sewage and pose a major problem with respect to disease transmission.

WORKSHEET DESCRIPTION

The worksheet is used to estimate the increase in the hydraulic overflow rate due to CR, and to determine the decrease in suspended solids (SS) and BOD removal efficiencies as a function of the overflow rate. In order to calculate the decrease in treatment efficiencies, the average pre-CR efficiencies must be known. If the pre-CR treatment efficiencies of the primary clarifier cannot be determined from plant records, then an estimate must be made based on the typical performance graphs in Fig. II-2, which can be used to determine the pre-CR suspended solids and BOD removal efficiencies based on the average hydraulic overflow rate before CR. As shown in the example, for an overflow rate of 1,000 gpd/sq ft, the suspended solids removal would be approximately 58% and the BOD removal 32%. The pre-CR and CR removal efficiencies will be used in later worksheets to calculate the efficiencies of the various secondary treatment processes.

The worksheet also provides for the calculations of primary sludge production during CR, which will be used to evaluate the solids handling equipment and digester operation. The concentration of the sludge will probably not change significantly during CR. For this reason the average pre-CR concentration will serve to calculate the volume of sludge produced during CR.



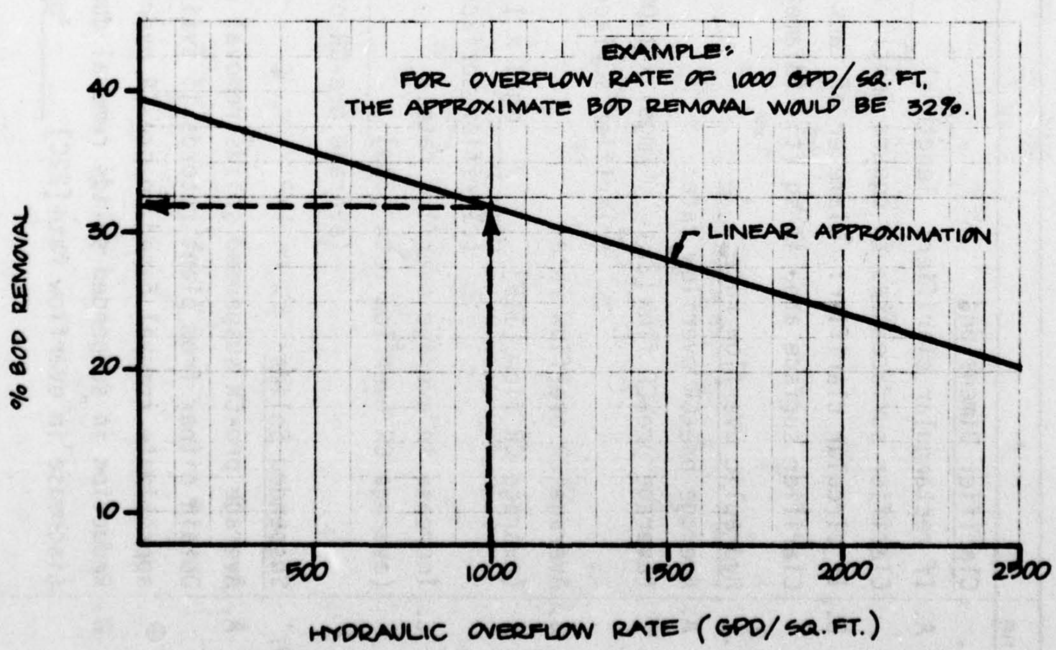


Fig. II-2. Suspended Solids and BOD Removal Efficiencies - Primary Clarifier.

WORKSHEET

Primary Clarifier

Line		Quantity	Units	Line
21.	Clarifier Dimensions			
A.	If rectangular clarifier: length = ____ft; width = _______ft:			
	Clarifier surface area in square feet: (length ___ft) x (width ____ft) =	______	sq ft	21A
B.	If circular clarifier: diameter of tank = ______ft:			
	Clarifier surface area in sq ft: (diameter ___ft) x (diameter __ft) x 0.785 =	______	sq ft	21B
22.	Hydraulic overflow rate			
A.	Average pre-CR overflow rate:			
	(average pre-CR flow [2A]_____mgd) x 1,000,000 ÷			
	(clarifier surface area [21A or 21B] _________sq ft) =	______	gpd/sq ft	22A
B.	Average CR overflow rate:			
	(average CR flow [11B] ________mgd) x 1,000,000 ÷			
	(clarifier surface area [21A or 21B]_________sq ft) =	______	gpd/sq ft	22B
C.	Increase in average overflow rate:			
	(average CR overflow rate [22B]___________gpd/sq ft) -			
	(average pre-CR overflow rate [22A]__________gpd/sq ft)	______	gpd/sq ft	22C
23.	Suspended Solids			
A.	Average pre-CR suspended solids removal by primary clarifier alone:			
	Obtain either from plant records if available: or, determine approximate			
	approximate removal based on pre-CR overflow rate (using Fig. II-2, p. II-14) =	______	%	23A
B.	Reduction in suspended solids removal due to CR:			
	(increase in overflow rate [22C] ______gpd/sq ft) ÷ (1000 gpd/sq ft) x 14 =	______	%	23B

Primary Clarifier (contd)

Line		Quantity	Units	Line
23. C.	Average CR suspended solids removal:			
	(average pre-CR removal [23A] ___%) - (reduction in solids removal [23B]__ %) =	______	%	23C
D.	Average CR solids production:			
	(average CR solids load [12B] _______lb/day) x (CR removal [23C] ___%) x 0.01 =	______	lb/day	23D
24.	Organic BOD			
A.	Average pre-CR BOD removal by primary clarifier alone:			
	Obtain either from plant records, if available; or, determine			
	approximate removal based on pre-CR overflow rate (using Fig. II-2, p. II-14)	______	%	24A
B.	Reduction in BOD removal due to CR:			
	(increase in overflow rate [22C]____gpd/sq ft) ÷ (1000 gpd/sq ft) x 8 =	______	%	24B
C.	Average CR BOD removal:			
	(average pre-CR removal [24A] ___%) - (reduction in BOD removal [24B] ___%) =	______	%	24C
D.	Average pounds of BOD removed before CR:			
	(average pre-CR BOD load [4C]______lb/day) x (pre-CR BOD removal [24A] __%) x 0.01=	______	lb/day	24D
E.	Average pounds of BOD removed during CR:			
	(average CR BOD load [13B]_______lb/day) x (CR BOD removal [24C] __%) x 0.01 =	______	lb/day	24E
25.	Sludge Production			
A.	Average pre-CR primary sludge concentration in % solids*	______	% solids	25A*
B.	CR primary sludge volume (based on pre-CR sludge concentration)			
	(CR solids production [23D] _____lb/day) ÷ 8.34 lb/gal ÷			
	(pre-CR sludge concentration [25A] __%) x 100 =	______	gpd	25B

* Estimate from plant records

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

The major problems that will be encountered with primary sedimentation during CR are decreased solids and BOD removal as a result of the increase in the hydraulic overflow rate. Fig. II-3 shows a generalized relationship of how these factors will affect the operation of a primary clarifier. The decreases in both BOD and solids removal, however, will be gradual and no "failure" of the system will result and the major impact of these decreases in treatment will be to increase the load on the secondary treatment systems.

The troubleshooting guide which follows provides more detailed information on how to deal with these operational problems.

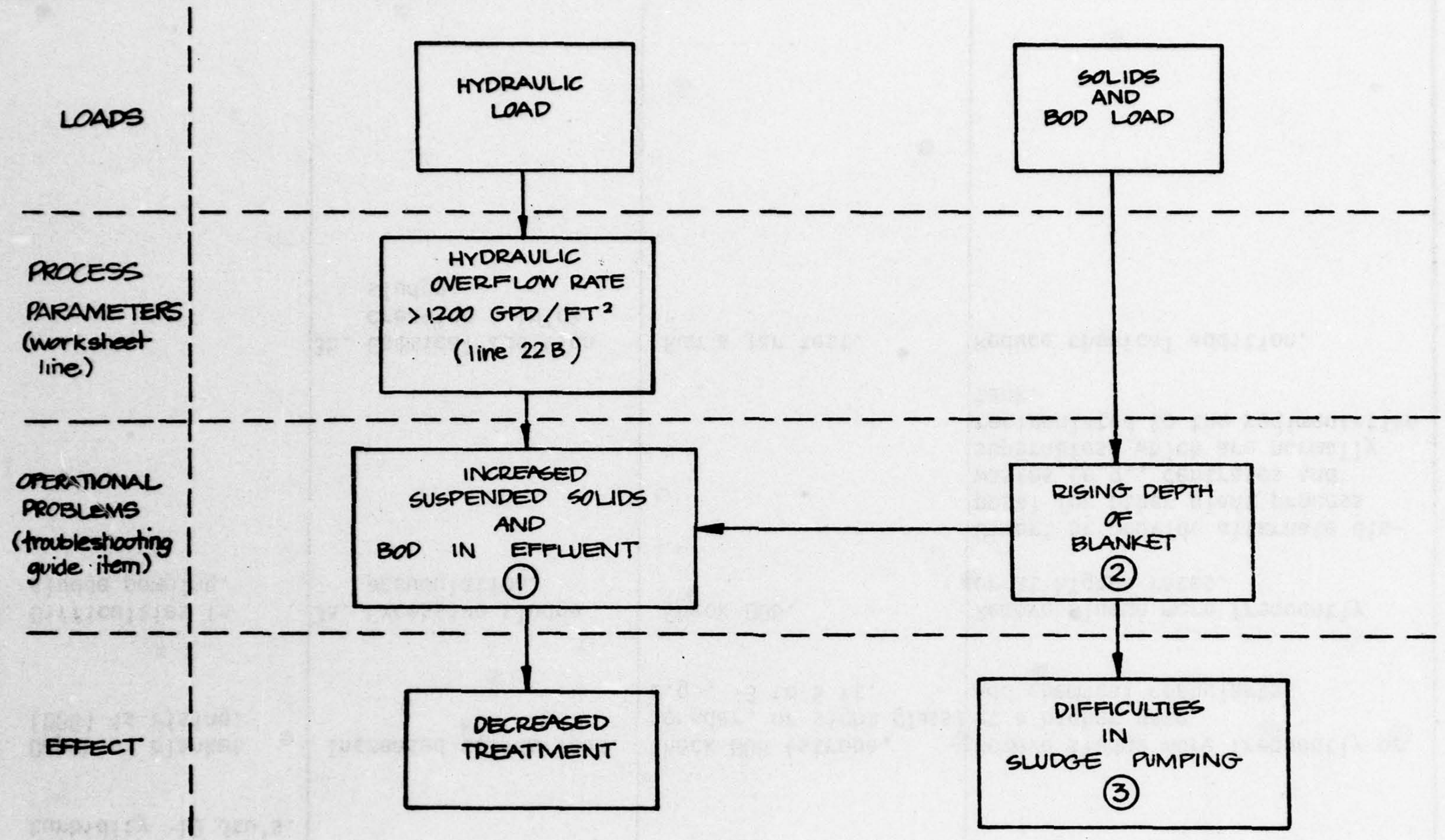


Fig. II-3. Primary Clarifier Operational Flow Chart

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Increased suspended solids in clarifier effluent. E.g., turbidity >10 Jtu's.	High overflow rate. e.g., >1,200 gpd/sq ft.	Check overflow rate Line 22B.	Refer to flow reduction methods.
2. Depth of blanket (DOB) is rising.	Increased solids load.	Check DOB (strobe, sounder, or sight glass) e.g., >3 to 5 ft.	Remove sludge more frequently or at a higher rate. Add chemical coagulants.
3. Difficulties in sludge pumping.	3a. Excessive sludge accumulation.	Check DOB.	Remove sludge more frequently or at higher rates. Divert or provide alternate disposal for other plant process wastes (e.g., centrates and supernates) which are normally recirculated to the sedimentation tank.
	3b. Chemical addition creating a thick sludge.	Run a jar test.	Reduce chemical addition.

LABORATORY/PROCESS CONTROL TESTS

The most useful tests for monitoring the operation of primary clarifiers during CR are the depth of blanket and jar tests. The depth of blanket test will indicate a potential rising blanket problem, thus allowing process modifications before the effluent suspended solids concentration becomes too great. The jar test is used to determine the quantity and to evaluate the effectiveness of the addition of chemical coagulants. Typical coagulants and typical concentrations used are as follows: polymers (0.5 mg/l), ferric chloride (20 mg/l Fe), alum (100 mg/l).

One word of caution is in order regarding the use of chemical coagulants in the primary clarifier. The use of these coagulants can increase the volume of waste solids requiring disposal by up to fifty percent. Because the solids handling systems are going to often be overtaxed during CR, it is recommended that the use of coagulants be limited to periods of peak flow to minimize the solids production.

TRICKLING FILTER

PROCESS DESCRIPTION

A trickling filter consists of one or more biological filters and a secondary clarifier. The filters consist of a bed of packed media, typically rock four to six feet deep, over which the wastewater is passed to contact micro-organisms that grow attached to the media. The BOD of the wastewater is removed by the micro-organisms that use the organic waste material as food. Excessive accumulation of micro-organisms is prevented by sloughing of micro-organisms from the media, which are then removed from the process effluent by the secondary clarifier.

Since trickling filters are designed primarily to remove BOD from the wastewater, it is important to be able to evaluate the filter performance during the increased organic loads associated with CR. The treatment efficiency of a trickling filter is dependent upon the amount of contact between the micro-organisms in the filter media and the organic matter in the wastewater. The efficiency can be related primarily to three operating parameters: the organic loading applied to the filter; the hydraulic flow through the filter; and the filter recirculation ratio. Of these three parameters, changes in the organic loading have the greatest influence on filter efficiency. Although the BOD removal efficiency can normally be improved by increasing the number of times the wastewater is recirculated through the filter, the increased hydraulic load to the plant during CR may limit the amount of wastewater that can be recirculated.

WORKSHEET DESCRIPTION

The worksheet is used to estimate the decrease in the BOD removal efficiency of the trickling filter as a function of the increasing organic loading (measured as lb BOD/day/1,000 cu ft) caused by CR. The rate of decrease in treatment efficiency is greatest up to a loading of about 40 lb BOD/day/1,000 cu ft. At loadings greater than 40 the efficiency drops off at a more gradual rate. For this reason the calculations for the reduction in treatment due to CR are broken down into three sections depending on the range of the change in organic loading. In order to determine the CR efficiency of the filter, an average pre-CR efficiency must be determined either from plant records, or from pre-CR BOD loads and primary BOD removal as shown in Line 35.

The worksheet is also used to determine the secondary clarifier hydraulic overflow rates and the solids production.

WORKSHEET

Trickling Filter

Line		Quantity	Units	Line
31.	<u>Trickling Filter Dimensions</u>			
A.	Filter surface area: diameter of filter bed = _____ft.			
	(diameter _____ft) x (diameter _____ft) x 0.785 =	_____	sq ft	31A
B.	Filter volume: depth of filter = _____ft.			
	(surface area [31A]_____sq ft) x (depth _____ft) =	_____	cu ft	31B
32.	<u>Organic BOD</u>			
A.	Average pre-CR % BOD removal in trickling filter:			
	Obtain either from plant records if available; or, determine from pre-CR			
	plant influent and effluent BOD loads and primary BOD removal, as shown			
	on Line 35: Removal =	_____	%	32A
B.	Pre-CR pounds of BOD entering trickling filter:			
	(average pre-CR BOD load [4C]_____lb/day) - (pre-CR primary BOD removal [24D]_____lb/day)	_____	lb/day	32B
C.	CR pounds of BOD entering trickling filter:			
	(CR BOD load [13B]_____lb/day) - (CR primary BOD removal [24E]_____lb/day) =	_____	lb/day	32C
D.	Pre-CR organic loading			
	(pre-CR BOD [32B]_____lb/day) x 1000 ÷ (filter volume [31B]_____cu ft) =	_____	$\frac{\text{lb/day}}{\text{1000 cu ft}}$	32D
E.	CR organic loading			
	(CR BOD [32C]_____lb/day) x 1000 ÷ (filter volume [31B]_____cu ft) =	_____	$\frac{\text{lb/day}}{\text{1000 cu ft}}$	32E

Line		Quantity	Units	Line
33.	Percent BOD Removal			
A.	If pre-CR organic loading [32D] and CR organic loading [32E] are both less than 40 lb/day/1000 cu ft, then the reduction in BOD removal will be:			
	(CR loading [32E] ____ lb/day/1000 cu ft - pre-CR loading [32D] _____ lb/day/1000 cu ft) ÷ 100 x 75 =	______	%	33A
B.	If pre-CR organic loading [32D] is less than 40, but the CR loading is between 40 and 150, then the reduction in BOD removal will be:			
	(1) (40 - pre-CR loading [32D] ____ lb/day/1000 cu ft) ÷ 100 x 75 = __% (1)			
	(2) (CR loading [32E] ______ lb/day/1000 cu ft - 40) ÷ 100 x 17 = __% (2)			
	(3) Total reduction in BOD removal = (1) __% + (2) __% =	______	%	33B
C.	If pre-CR organic loading [32D] is between 40 and 150, but the CR loading is greater than 150, then the reduction in BOD removal will be:			
	(1) (150 - pre-CR loading [32D] _____ lb/day/1000 cu ft) ÷ 100 x 17 = __% (1)			
	(2) (CR loading [32E] ______ lb/day/1000 cu ft - 150) ÷ 100 x 5 = __% (2)			
	(3) Total reduction in BOD removal = (1) __% + (2) __% =	______	%	33C
D.	If both the pre-CR loading [32D] and CR loading [32E] are greater than 150, then the reduction in BOD removal will be:			
	(CR loading [32E] ____ lb/day/1000 cu ft - pre-CR loading [32D] ________ lb/day/1000 cu ft) ÷ 100 x 5	______	%	33D
E.	CR percent BOD removal			
	(pre-CR removal [32A] __%) - (reduction [33A, B, C or D] __%) =	______	%	33E
F.	CR pounds of BOD removed:			
	(CR BOD [32C] _______ lb/day) x (CR removal [33E] __%) x 0.01 =	______	lb/day	33F

Line		Quantity	Units	Line
34.	Seconday Clarifier			
A.	If rectangular clarifier: length = ____ft; width = ______ft.			
	Clarifier surface area in sq ft: (length ____ft) x (width ___ft) =	______	sq ft	34A
B.	If circular clarifier: diameter = _____ft.			
	Clarifier surface area in sq ft: (diameter ___ft) x (diameter ____ft) x 0.785	______	sq ft	34B
C.	Average hydraulic overflow rate:			
	(average CR flow [11B] ___mgd) x 1,000,000 ÷			
	(clarifier surface area [34A or 34B] _____sq ft) =	______	gpd/sq ft	34C
D.	Peak hydraulic overflow rate:			
	(peak CR flow [11C] _____mgd) x 1,000,000 ÷			
	(clarifier surface area [34A or 34B] _____sq ft) =	______	gpd/sq ft	34D
E.	Solids production (based on 0.5 lb solids per lb BOD removed):			
	(CR BOD removal [33E] ______lb/day) x 0.5 lb solids/lb BOD removed =	______	lb/day	34E
F.	Average pre-CR trickling filter clarifier sludge concentration*	______	% solids	34F*
G.	CR sludge volume produced by trickling filter clarifier (based on pre-CR sludge concentration):			
	(CR trickling filter clarifier solids production [34E] _____lb/day) ÷ 8.34 lb/gal			
	÷ (pre-CR sludge concentration [34F] __%) x 100 =	______	gpd	34G

* from plant records

Trickling Filter (contd)

Line		Quantity	Units	Line
35.	Pre-CR BOD removal efficiency (skip this calcualtion if trickling filter efficiency is available from plant records)			
A.	Pre-CR pounds of BOD entering trickling filter: (pre-CR BOD load [4C]___lb/day) - (pre-CR primary BOD removal [24D]____lb/day) =	______	lb/day	35A
B.	Pre-CR BOD removal (pre-CR BOD load to filter [35A]____lb/day) - (pre-CR BOD effluent [4D]____lb/day)	______	lb/day	35B
C.	Pre-CR percent BOD removal: (pre-CR BOD removal [35B]___lb/day) ÷ (pre-CR BOD load to filter [35A]___lb/day) x 100	______	%	35C

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

The operation of a trickling filter during CR will be affected primarily by the increases in organic and hydraulic loadings. Increases in the organic loading will result in increased growth and increased oxygen consumption by the micro-organisms within the filter as well as potential ponding. Increases in the hydraulic load will result in an increased overflow rate in the final clarifier and also will probably result in a decreased recirculation ratio because of limited pumping capacity to the filter. It is anticipated that the increased load during CR will, in some instances, produce nusiance problems such as odors and filter flies. Fig. II-4 shows how the above factors can lead to potential operational problems during CR. A more detailed description of these problems, their causes and possible solutions is given in the troubleshooting guide.

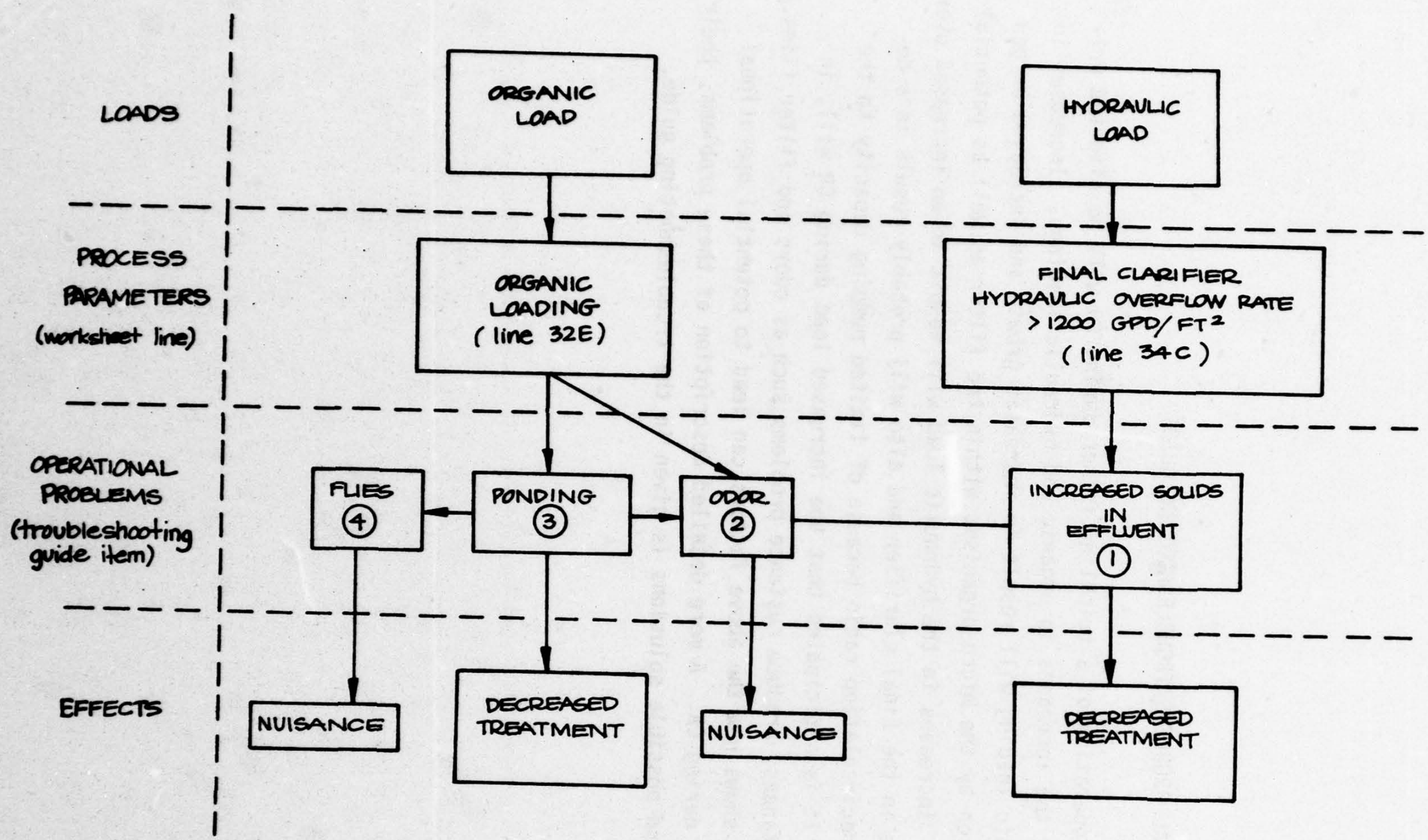


Fig. II-4. Trickling Filter Operational Flow Chart.

TROUBLESHOOTING GUIDE

Trickling Filter

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Increase in clarifier effluent suspended solids.	1a. Final clarifier hydraulically overloaded.	Overflow rate (Line 34C and 34D) < 800 gpd/sq ft	Refer to flow reduction section to reduce the hydraulic load.
	1b. Insufficient solids wasting.	Depth of blanket	Increase clarifier underflow rate. Polymer addition to clarifier influent.
2. Odors (Rotten egg smell)	2a. Excessive organic loading.		Refer to section on load reduction to reduce BOD load.
	2b. Insufficient ventilation.	Inspect media voids and underdrain for plugging.	Increase recirculation rates to filter. Clean and open underdrain. Add forced ventilation equipment.
3. Filter ponding. (Small pools of water upon and in the filter bed.)	3a. Excessive organic loading.		Increase recirculation > 200gpd/sq ft Reduce BOD from primary treatment unit. Refer to troubleshooting guide.
	3b. Insufficient sloughing of excessive biological growth caused by excessive organic loading.	Slime growth clogging filter voids.	Flush media with high pressure stream of water. Rake surface media to loosen voids, dose with Cl_2 to control growth. (Cl_2 should not exceed 1 to 2 mg/l residual.)
	3c. Poor housekeeping.	Visual inspection of filter.	Remove leaves, debris, etc. from filter media.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
4. Filter flies. (A small, gnat-sized moth-like fly.)	4a. Ponding (See 3 above)	Visual inspection.	Remove excess growth as described in 3a.
		Microscopic examination of slime growth — for dark brown wormlike larvae.	Flush filter and/or chlorinate to produce a residual of 1 to 2 mg/l.
		Hydraulic loading should be greater than 200 gpd/sq ft.	Prevent completion of the filter fly's life cycle.
	4b. Plant grounds can provide breeding grounds for flies from accumulation of standing H_2O.	Inspect grounds for pools of H_2O and slime growth from spillover of wastewater.	Maintain grounds so as not to provide sanctuary for flies.

LABORATORY/PROCESS CONTROL TESTS

The trickling filter requires mostly visual observation for identification of the problems that may occur, such as ponding and filter flies. Microscopic examination of the slime on the media, however, will indicate the onset of filter flies if small worm-like larvae are present.

Measurement of the dissolved oxygen of the filter effluent will allow detection of when the organic load exceeds the natural aeration capacity of the filter. If no dissolved oxygen is detectable, then increased ventilation should be provided if possible.

ACTIVATED SLUDGE

PROCESS DESCRIPTION

Activated sludge is an aerobic, biological treatment process which is unique in that biological sludge (micro-organisms) are separated and returned to the biological reactor. Fig. II-5 shows a generalized activated sludge system consisting of two major components, the aeration tank or biological reactor, and the secondary clarifier or solids separator. Air is introduced into the aeration tank to provide oxygen for the micro-organisms and to mix the influent wastewater with the micro-organisms. In the aeration tank BOD is removed by two mechanisms: the micro-organisms either oxidize the BOD to carbon dioxide or use it for synthesis of new microbial mass. After aeration the mixture of wastewater and micro-organisms (called the mixed liquor) is pumped to the secondary clarifier where the biological solids are removed from the process effluent by sedimentation. Part of the settled sludge is returned to mix with the influent wastewater to control the mixed liquor suspended solids (MLSS) concentration in the aeration tank and the remainder is wasted by pumping to the digester or other sludge handling process.

Many modifications of the activated sludge process have been developed, some of which are: step aeration, complete mix, contact stabilization, extended aeration, and oxidation ditch. Since all of these systems consist of an aerated reactor and solids separation, this manual will be applicable to each of these modifications. However, specific threshold values for some parameters may vary somewhat from process to process.

Activated sludge is perhaps the most complex sewage treatment process

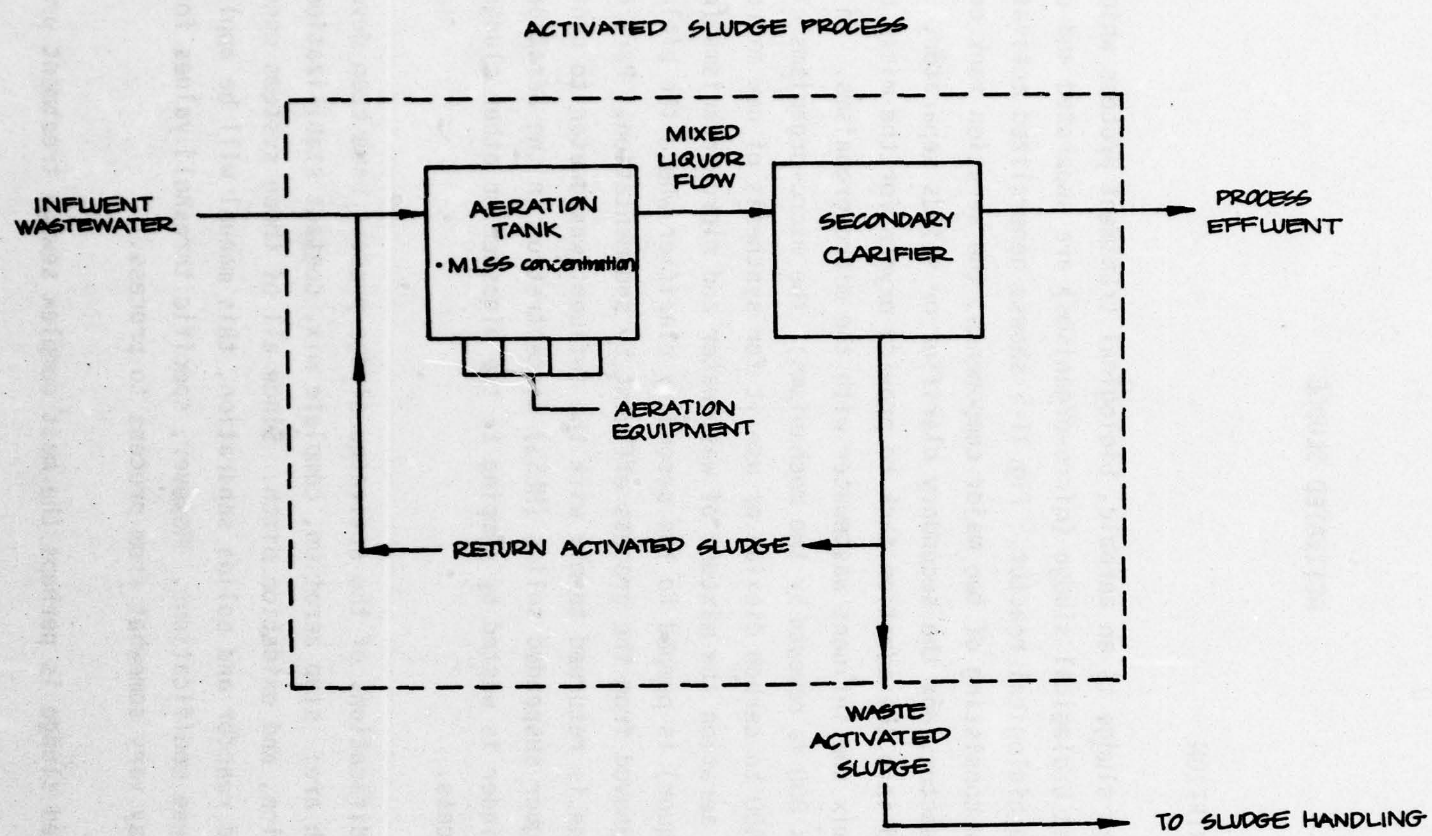


Fig. II-5. Generalized Activated Sludge Process.

and functions efficiently only with the proper control of a number of interrelated parameters. Because some parameters are fairly sensitive and must be controlled within a fairly narrow range, activated sludge plants must be closely monitored during CR, especially when sudden changes in hydraulic and organic loadings are anticipated. When activated sludge is operated within process limits and is given proper control, the process will provide high degrees of treatment. However, when process limits are exceeded, or when insufficient control is given, the process can undergo a sudden decrease in treatment or complete failure. The following worksheet will aid in assessing the impact of CR on the operation of activated sludge plants and help to identify and correct critical problems which may occur.

WORKSHEET DESCRIPTION

The worksheet predicts the impact of CR on the activated sludge process by comparing the projected waste load to the capacity of the existing tankage and aeration capacity. The worksheet predicts values for two key loading parameters (final tank overflow rate and food-to-micro-organism ratio) and also tests the sufficiency of the aeration capacity. Comparison of these projected values to known adequate values allows isolation of potential problem areas in the troubleshooting guide.

WORKSHEET

Activated Sludge

Line		Quantity	Units	Line
41	Aeration Tank			
A.	If rectangular aeration tank: length ____ft; width ____ft; depth ____ft;			
	Tank volume in cubic feet = (length ____ft) x (width ____ft) x (depth ____ft) =	______	cu ft	41A
B.	If circular aeration tank: diameter of tank ____ft; depth ____ft;			
	Tank volume in cu ft = (diameter ____ft) x (diameter ____ft) x (depth ____ft) x 0.785	______	cu ft	41B
42	Secondary Clarifier			
A.	If rectangular clarifier: length ____ft; width ____ft.			
	Clarifier surface area in square feet = (length ____ft) x (width ____ft) =	______	sq ft	42A
B.	If circular clarifier: diameter = ______ft.			
	Clarifier surface area in sq ft = (diameter ____ft) x (diameter ____ft) x 0.785 =	______	sq ft	42B
43	CR BOD Load to System			
A.	Average Load:			
	Pounds of BOD per day = (average CR BOD load [13B] ______lb/day) - (average pounds of BOD removed in primary [24E] ____lb/day) =	______	lb/day	43A
	Note: if there is no primary treatment prior to activated sludge, enter zero for line 24D.			
B.	Peak Load:			
	Pounds of BOD per day = (average CR BOD load to system [43A] ____lb/day) x (peaking factor [2C] ____) =	______	lb/day	43B
44	Peak Return Activated Sludge Flow			
	Maximum return sludge pump capacity = ______gpm			
	Peak return sludge flow = (pump capacity ____gpm) ÷ 694 gpm/mgd =	______	mgd	44

Line		Quantity	Units	Line
45	Maximum Mixed Liquor Suspended Solids			
A.	Pounds of MLSS in aeration tank during CR:			
	(30 lb/day-sq ft) x (clarifier surface area [42A or 42B] ____ sq ft) =	____	lb/day	45A
B.	Pounds of MLVSS in aeration tank:			
	(MLSS [45A] ____ lb/day) x (% volatile suspended solids*) ÷ 100 =	____	lb/day	45B
C.	Projected MLSS concentration in aeration tank:			
	(mass of MLSS [45A] ____ lb/day) x 0.12 gal/lb ÷			
	(average CR flow [11B] ___ mgd + return flow [44] ___ mgd) =	____	mg/l	45C
D.	Projected MLVSS concentration in aeration tank:			
	(MLSS [45C] ____ mg/l) x __ volatile suspended solids*) ÷ 100 =	____	mg/l	45D
46	Minimum Aeration Tank F/M Ratio			
	(average BOD load [43A] ____ lb/day) ÷ (mass of MLVSS [45B] ____ lb/day) =	____	none	46
47	Sufficiency of Aeration Capacity			
	Note: Use 47A and B if system has mechanical aeration equipment; use 47C, D, and E if system has diffused aeration equipment			
A.	Mechanical aerators: total horsepower of all aerators = ____ hp			
	Oxygen delivered = (total horsepower ___ hp) x 48 lbs oxygen/hp-day =	____	lb/day	47A
B.	Maximum BOD removal capability of mechanical aeration equipment:			
	BOD removed = (oxygen delivered [47A] ____ lb/day) ÷ 1.25 lb oxygen/lb BOD =	____	lb/day	47B
C.	Diffused aeration: blower rating = ____ cfm; number of blowers = ____.			
	Air delivered = (blower rating ____ cfm) x (number of blowers ___) x 1440 min/day =	____	cfd	47C
D.	Maximum BOD removal capability of coarse bubble diffused air system			
	BOD removed = (air delivered [47C] ___ cfd) ÷ (1600 lb air/lb BOD) =	____	lb/day	47D

* from plant records

Activated Sludge (contd)

Line		Quantity	Units	Line
47				
E.	Maximum BOD removal capability of fine bubble diffused air system:			
	BOD removed = (air delivered [47C] ____cfd) ÷ (1200 lb air/lb BOD) =	______	lb/day	47E
F.	Average excess aeration capacity:			
	(BOD removal capability [47B or 47D or 47E] ________ lb/day) -			
	(average CR BOD load to system [43A] __________ lb/day) =	______	lb/day	47F
G.	Peak excess aeration capacity:			
	(BOD removal capability [47B or 47D or 47E] __________ lb/day) -			
	(peak CR BOD load to system [43B] __________ lb/day) =	______	lb/day	47G
48.	Secondary Clarifier			
A.	Average hydraulic overflow rate:			
	(average CR flow [11B] _____ mgd) x 1,000,000 ÷			
	(clarifier area [42 A or 42B] ________ sq ft) =	______	gpd/sq ft	48A
B.	Peak hydraulic overflow rate:			
	(peak CR flow [11C] ____ mgd) x 1,000,000 ÷ (clarifier area [42A or 42B] ______ sq ft)	______	gpd/sq ft	48B
C.	Biological solids production:			
	(average CR BOD load to system [43A] _____ lb/day) x 0.5 lb solids/lb BOD =	______	lb/day	48C
D.	Sludge volume based on average pre-CR sludge concentration*:			
	(mass of solids [48C] _____ lb/day) ÷ 8.34 lb/gal ÷			
	(average waste sludge concentration ____% solids*) x 100 =	______	gpd	48D

* from plant records

Line	
49.	Sufficiency of Aeration Capacity
A.	Is average excess aeration capacity [47F] negative?
	Yes: Overload will deplete mixed liquor dissolved oxygen. Sludge bulking and decreased treatment may result. Reduce BOD load by bypass or reduction of industrial contribution. Use maximum aeration capacity.
	No: Check peak value [47G] below.
B.	Is peak excess aeration capacity [47G] negative?
	Yes: Overload at peak values (see above). Flow equalization can relieve problem.
	No: System should be aerobic with maximum aeration.
50.	Secondary Clarifier Hydraulic Overflow Rate
A.	Is secondary clarifier average overflow rate [48A] greater than 1200 gpd/sq ft?
	Yes: Hydraulic overflow will result in solids washout and process failure. Reduce hydraulic flow.
	No: Check peak flow.
B.	Is secondary clarifier peak overflow rate [48B] greater than 1200 gpd/sq ft?
	Yes: Flow equalization measures may reduce or eliminate problem.
	No: In absence of bulking, final tank should operate correctly.
51.	Minimum Aeration Tank Food-to-Micro-organism Ratio
	Is minimum F/M ratio [46] greater than 0.5?
	Yes: Probable bulking may result. Decrease F/M ratio by reducing organic load (see [49A]) and maintaining maximum MLSS concentration.
	No: Bulking can be controlled by adjustment of F/M ratio to near 0.35.

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

Most operational problems that might occur during CR will be the result of increases in the organic and/or hydraulic loads. Fig. II-6 shows a generalized relationship between these loads, process parameters and potential operational problems. This section consists of a brief description of the problems expected to occur most frequently, followed by a simplified troubleshooting guide indicating the probable cause, laboratory or process control checks, and suggested solutions.

Successful treatment by the activated sludge process requires proper solids removal in the secondary clarifier, which can only result when the overflow rate does not exceed sludge settleability. Sludge settleability is usually reduced by bulking which, as indicated in Fig. II-6, is influenced by increases in the organic load and the overflow rate, which is directly related to the hydraulic load. Increasing the organic load increases the growth rate of the micro-organisms and their associated oxygen requirements. If the mixed liquor solids concentration is not sufficient to handle the increase in the growth rate ($F/M > 0.5$) or if there is insufficient aeration capacity (excess aeration is negative) sludge settleability will have a tendency to decrease, producing a "bulking sludge". A bulking sludge is indicated by an increase in the sludge volume index (SVI) usually caused by increased presence of filamentous organisms. The best settling sludges require an overflow rate below 1,200 gpd/sq ft and bulking sludges require an even lower overflow rate. An overflow rate in excess of sludge settleability will result in a rising sludge blanket throughout the clarifier which, if not corrected, will cause the effluent to degrade, leading to a loss of biological solids and ultimately resulting in process failure. In addition to this loss of solids, excessive loadings can result in the minor problems of rising sludge clumps and foaming.

The troubleshooting guide provides a more detailed description of the above problems and their solutions.

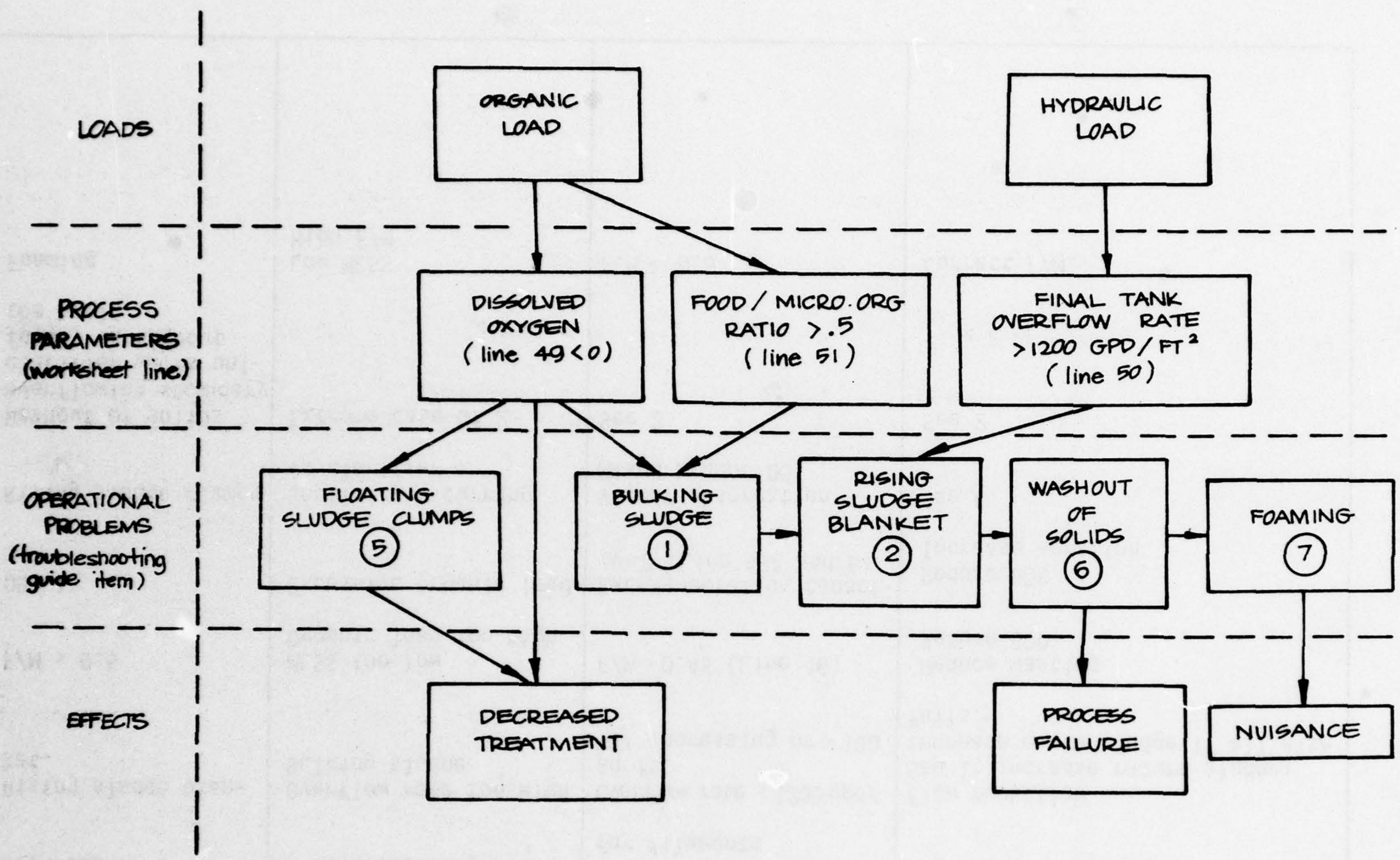


Fig. II-6. Activated Sludge Operational Flow Chart.

TROUBLESHOOTING GUIDE

Activated Sludge

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Bulking sludge Increasing SVI SVI > 100	High F/M Low DO Filamentous organisms	F/M > 0.5 DO < 1 mg/l Microscopic examination for filaments	Correct F/M Increase DO Cl_2 return sludge.
2. Rising sludge blanket.	Overflow rate too high Bulking sludge	Overflow rate < 1200 gpd/sq ft. SVI increasing or > 100	Flow reduction See 1; increase return sludge; increase waste sludge if all else fails.
3. F/M > 0.5	MLSS too low Organic load too high	F/M > 0.45 (Line 46)	Reduce wasting. Reduce BOD
4. DO< 1	Excessive organic load	Excess aeration capacity<0 (Line 49A and B)	Reduce BOD Increase aeration
5. Rising sludge clumps	Septicity occurring in clarifier	Visual observation Mixed Liquor DO	See 4.
6. Washout of solids overflowing secondary clarifier weirs uniformly throughout the basin	Extreme case of 2	See 2	See 2
7. Foaming	Low MLSS High F/M	F.M < 0.5	Correct F/M

LABORATORY/PROCESS CONTROL TESTS

Sufficient information to monitor the operation of an activated sludge plant and to determine major problems can be obtained from a few simple tests. One series of settlometer, sludge blanket depth, microscopic examination and dissolved oxygen tests can be run in about 90 minutes so that multiple tests can be run each day as needed during CR.

The following easy-to-perform tests will be useful in assessing conditions that are likely to occur during CR:

1. The depth of blanket test will detect a rising sludge blanket in the final clarifier to allow process modifications before solids washout occurs.

2. The measurement of settleable solids test indicates the solids/liquid separation capability of the sludge that goes to the final clarifier. This test will provide the first indication of a bulking sludge and an increasing volume of settleable solids will probably precede a rising sludge blanket.

3. Microscopic examination of the mixed liquor suspended solids is a helpful aid and can confirm a predominance of filamentous organisms as the cause of a bulking sludge.

4. Measurement of the dissolved oxygen in the aeration tank will confirm insufficient aeration and can provide the basis for increasing mixed liquor aeration or other controls.

PONDS AND LAGOONS

PROCESS DESCRIPTION

Ponds and lagoons are large earthen basins used to retain wastewater and allow biological treatment to take place. For this manual, a lagoon is defined as a retention basin which uses artificial aeration to maintain aerobic conditions. On the other hand, a pond—whether aerobic, facultative, or anaerobic—relies on natural aeration. Ponds and lagoons are less sensitive to increased loadings because they are generally designed with long detention times of several days and rely on both sedimentation and biological activity to provide treatment. Treatment efficiency of both is affected by the organic load, hydraulic detention time, wastewater temperature, aeration capacity, and various other environmental factors. The aeration capacity of lagoons is easily defined while the natural aeration of ponds depends heavily upon local climatic conditions. Because of the wide variations in climate throughout the country, state design and operational guidelines for ponds should be used to determine acceptable loadings.

WORKSHEET DESCRIPTION

The worksheet analyzes ponds and aerated lagoons separately because of their different operating conditions. The BOD removal efficiency of a pond is based on areal BOD loading and hydraulic detention time. To simplify calculations, Fig. II-7 is used to determine an operational parameter "A" from the areal BOD loading, and Fig. II-8 is used to determine parameter "B" from the detention time. These two parameters relate the effect of changes

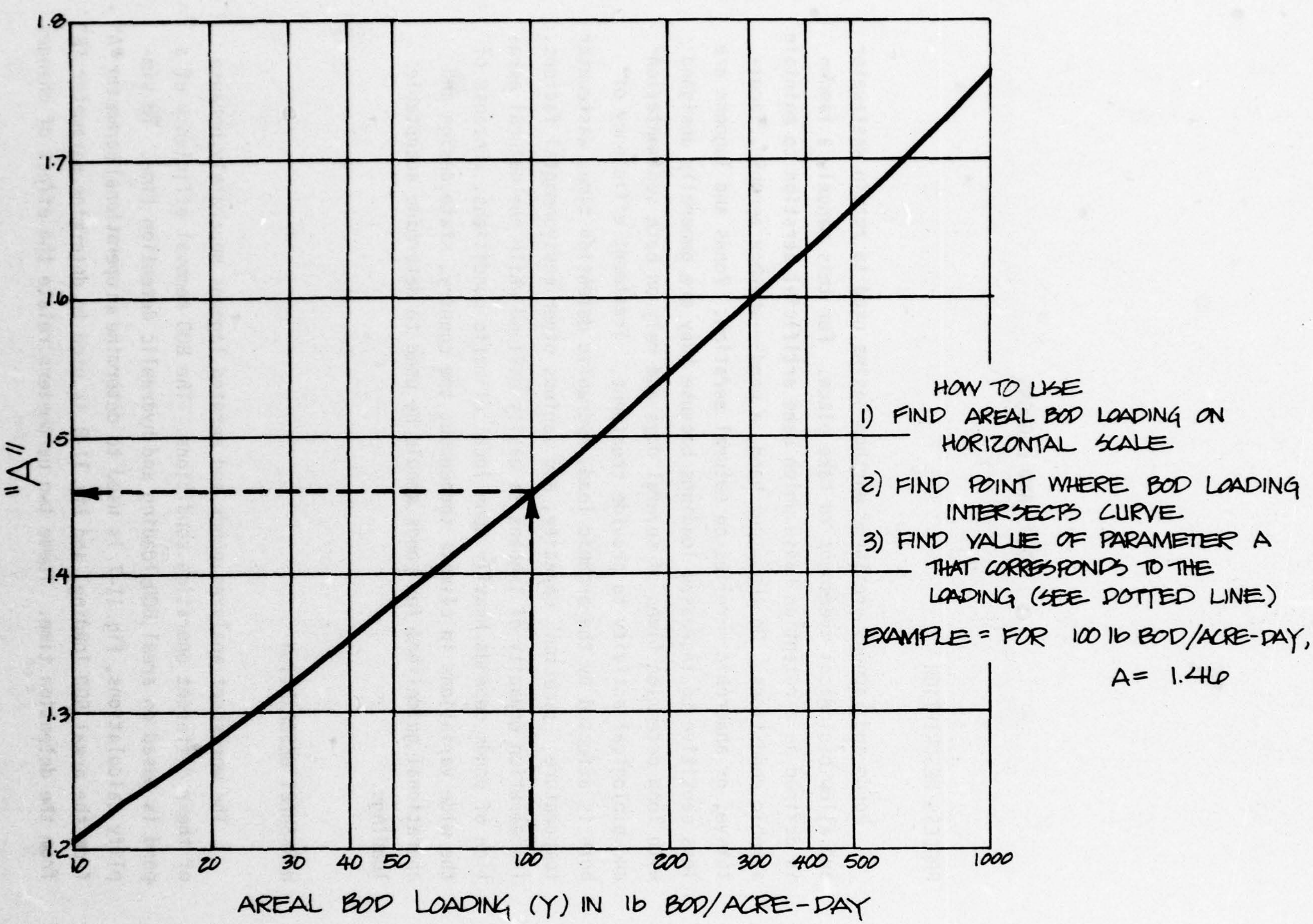


Fig. II-7. Parameter A as a Function of Areal BOD Loading - Ponds.

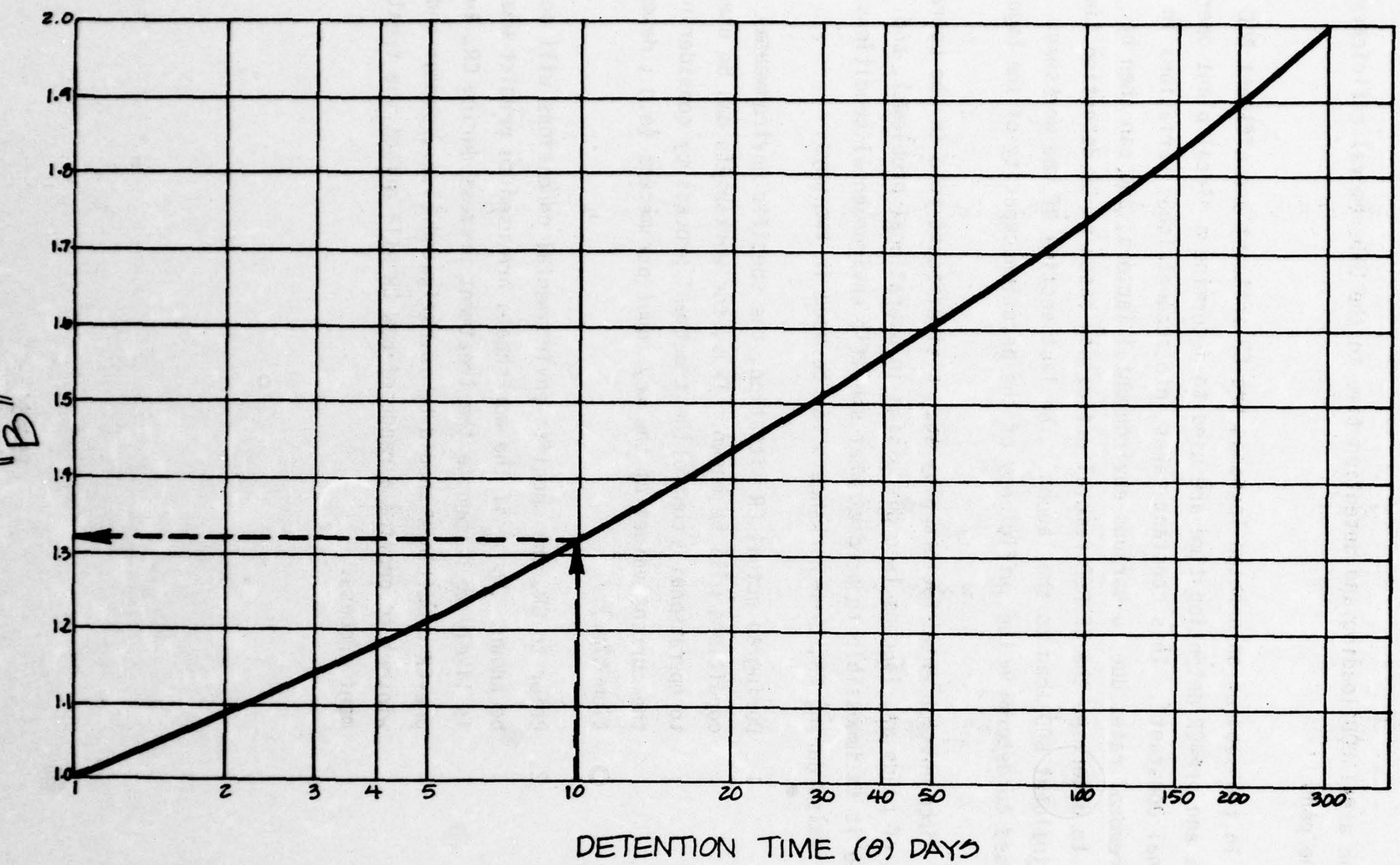


Fig. II-8. **Parameter B as a Function of Hydraulic Detention Time -Ponds.**

in the areal BOD loading and detention time to the BOD removal efficiency of the pond.

In the section on aerated lagoons, pre-CR influent and effluent BOD loads and pre-CR detention time are used to determine a "local plant operational constant". This constant takes into account local variations in BOD removal rates due to various environmental factors, and can then be used to determine the CR BOD removal efficiency based on CR detention time and influent BOD load to the lagoon. The last section of the worksheet is used to determine the sufficiency of the aeration capacity of the lagoon.

Since environmental factors play such a significant role in the operation of ponds and lagoons (see discussion in operational problems), and since it is impossible to predict what specific environmental conditions will exist during CR, these worksheets can be used in two ways:

1. During an actual CR situation, the specific environmental conditions will be known. Thus, the worksheets can be used to operationally control the treatment process by considering the current values of the key input parameters (e.g., detention time).

2. Prior to CR, the specific environmental conditions will not be known. Thus, if the worksheets are used to predict what is likely to happen to the treatment process during CR, two pre-CR conditions should be investigated (i.e., summer and winter) to provide a range of how CR will affect the treatment process.

Line		Quantity	Units	Line
55	General Basin Calculations			
A.	Volume: total surface area = ______ acres; depth = ______ ft.			
	volume of basin in gallons: (area ____ acres) x (depth __ ft) x 0.326 $\frac{MG}{acre\ ft}$ =	______	MG	55A
B.	Pre-CR pounds of BOD entering basin:			
	(average pre-CR load [4C] ____ lb/day) - (pre-CR primary removal [24D] ______ lb/day) =	______	lb/day	55B
	Note: if there is no primary treatment before basin, enter zero here			
C.	CR pounds of BOD entering basin:			
	(average CR BOD load [13B] ____ lb/day) - (CR primary removal [24E] ______ lb/day) =	______	lb/day	55C
	Note: if there is no primary treatment before basin, enter zero here			
D.	Pre-CR hydraulic detention time:			
	(basin volume [55A] ____ MG) ÷ (pre-CR flow [2A] ____ mgd) =	______	days	55D
E.	CR hydraulic detention time:			
	(basin volume [55A] ____ MG) ÷ (CR flow 11B ____ mgd) =	______	days	55E
F.	Ratio of pre-CR effluent BOD load to pre-CR influent BOD load:			
	(effluent BOD load [4D] ____ lb/day) ÷ (influent BOD load [55B] ____ lb/day) =	______	none	55F
G.	Pre-CR BOD removal efficiency of basin:			
	(1.0 - BOD ratio [55F] ____) x 100 =	______	%	55G
56	Pond BOD Removal Efficiency Calculations			
A.	Pre-CR areal BOD load:			
	(pre-CR BOD load [55B] ____ lb/day) ÷ (total basin surface area ____ acres) =	______	lb/acre-day	56A
B.	Using pre-CR areal BOD load in 56A, determine the pre-CR value of parameter A			
	using Fig. II-7 : Pre-CR value of parameter A =	______	none	56B

Line		Quantity	Units	Line
56	C. CR areal BOD load:			
	(CR BOD load [55C] ____ lb/day) ÷ (total basin surface area ____ acres) =	____	lb/acre-day	56C
	D. Using CR areal BOD load in 56C, determine the CR value of parameter A			
	using Fig. II-7: CR value of parameter A =	____	none	56D
	E. Effect of BOD load on efficiency:			
	(pre-CR A value [56B] ____) ÷ (CR A value [56D] ____) =	____	none	56E
	F. Using pre-CR detention time in 55D, determine the pre-CR value of			
	parameter B using Fig. II-8: Pre-CR value of parameter B =	____	none	56F
	G. Using CR detention time in 55E, determine the CR value of			
	parameter B using Fig. II-8: CR value of parameter B =	____	none	56G
	H. Effect of detention time on efficiency:			
	(CR B value [56G] ____) ÷ (pre-CR B value [56F] ____) =	____	none	56H
	I. CR BOD removal efficiency of pond:			
	(effect of BOD loading [56E] ____) x (effect of detention time [56H] ____) x			
	(pre-CR BOD removal efficiency [55G] ____ %) =	____	%	56I
	J. Reduction in efficiency due to CR:			
	(pre-CR removal [55G] __ % - CR removal [56I] __ %) ÷ (pre-CR removal [55G] __ %) x 100 =	____	%	56J
57	**Aerated Lagoons**			
	A. Local operational constant:			
	(1.0 ÷ BOD ratio [55F] ____ - 1.0) ÷ (pre-CR detention time [55D] ____ days) =	____	per day	57A
	B. Effect of CR detention time and operational constant on efficiency:			
	(CR detention time [55E] ____ days) x (operational constant [57A] ____ per day) =	____	none	57B

Line		Quantity	Units	Line
57	C. CR pounds of BOD in effluent per day:			
	(CR influent BOD [55C] ____ lb/day) ÷ (1.0 + effect of detention time [57B] ___) =	______	lb/day	57C
	D. CR BOD removal efficiency:			
	1.0 - (CR effluent BOD [57C] ____ lb/day ÷ CR influent BOD [55C] ____ lb/day) x 100 =	______	%	57F
	E. Reduction in efficiency due to CR:			
	(pre-CR efficiency [55G] __ % - CR efficiency [57D] __ %) ÷ (pre-CR efficiency [55G] __ %) x 100 =	______	%	57E
58	<u>Lagoon Aeration Capacity</u>			
	Note: Use lines 58A and B for lagoons with mechanical aeration systems; use line 58C,D, and E for those with diffused aeration systems.			
	A. Mechanical aerator: total horsepower of all aerators = ________ hp			
	Oxygen delivered = (total horsepower _____ hp) x 24 lb oxygen/hp-day =	______	lb/day	58A
	B. Maximum BOD removal capability of mechanical aeration equipment:			
	BOD removed = (oxygen delivered [58A] ____ lb/day) 1.5 lb oxygen/lb BOD =	______	lb/day	58B
	C. Diffused aeration: blower rating = ____ cfm; number of blowers = _____			
	Air delivered = (blower rating ____ cfm) x (number of blowers ___) x 1440 min/day =	______	cu ft/day	58C
	D. Maximum BOD removal capability of coarse bubble diffused air system:			
	BOD removed = (air delivered [58C] ____ cu ft/day) ÷ (1600 lb air/lb BOD) =	______	lb/day	58D
	E. Maximum BOD removal capability of fine bubble diffused air system:			
	BOD removed - (air delivered [58C] ____ cu ft/day) ÷ (1200 lb air/lb BOD) =	______	lb/day	58E
	F. Average excess aeration capacity:			
	(BOD removal capability [58B, or 58D or 58E] ________ lb/day) - (average CR BOD load to basin [55C] ____ lb/day) =	______	lb/day	58F

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

The operational problems that might occur during CR will be the result of the increased hydraulic and organic loads. Because ponds and lagoons rely more on "natural" phenomena than other treatment processes, environmental conditions such as sunlight, wind, ice, etc. existing during CR can have a significant impact on the available treatment capacity. Fig. II-9 shows a generalized relationship of various factors which will affect the operation of ponds and lagoons during CR. As shown in Fig. II-9, environmental factors are indicated by a dashed box and the solid boxes are used to indicate only those factors that are a direct result of CR.

The major problems with ponds and lagoons are: decreased treatment and odors caused by overloading and oxygen depletion. Neither of these will cause a failure of the system and therefore, these systems are less susceptible to overloads caused by CR.

LABORATORY/PROCESS CONTROL TESTS

The most useful laboratory test for monitoring lagoons and ponds is the concentration of dissolved oxygen. Absence of detectable dissolved oxygen will indicate potential odor problems and decreased treatment due to insufficient aeration.

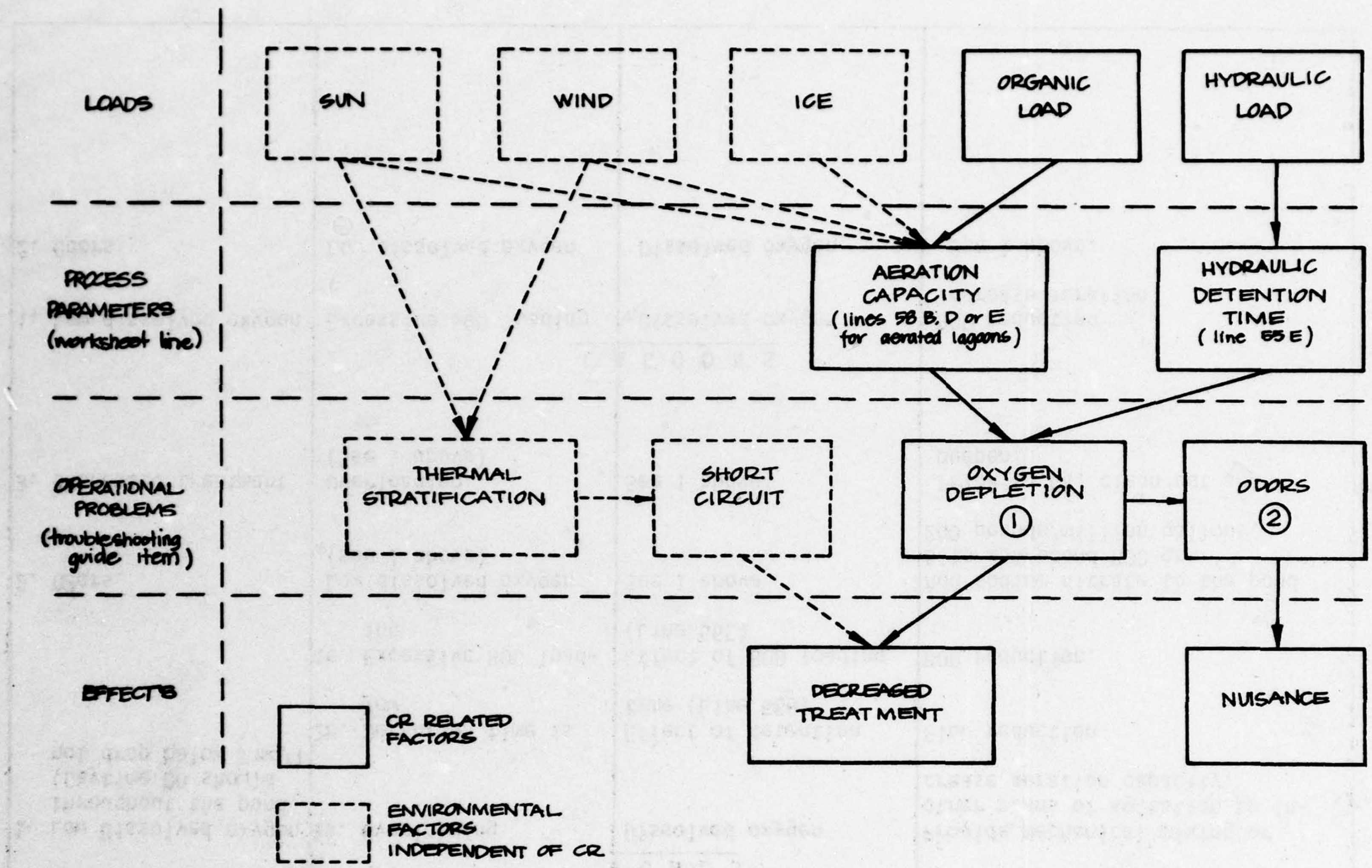


Fig. II-9. Ponds and Lagoons Operational Flow Chart.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
		PONDS	
1. Low dissolved oxygen throughout the pond. (Daytime DO should not drop below 3 mg/l	1a. Overloading	Dissolved oxygen	Provide mechanical mixing or other means of agitation to increase aeration capacity.
	1b. Detention time is low	Effect of detention time (Line 56H)	Flow reduction
	1c. Excessive BOD loading	Effect of BOD loading (Line 56E)	BOD reduction.
2. Odors	Low dissolved oxygen (see 1 above)	See 1 above	Add sodium nitrate to the pond 5 to 15%/pound BOD or 200 pounds/million gallons.
3. Decreased treatment	Overloading (See 1 above)	See 1 above	Prior to CR, clean out and deepen.
		LAGOONS	
1. Low dissolved oxygen	Excessive BOD loading	Dissolved oxygen	BOD reduction Increase aeration
2. Odors	Low dissolved oxygen	Dissolved oxygen	See 1 above.

SOLIDS HANDLING

PROCESS DESCRIPTION

The main objective in any solids handling process is the stabilization and/or disposal of the sludges produced during primary treatment and biological treatment. These sludges represent significant concentrations of organic solids and pathogenic organisms, and have a high potential to cause nuisance or disease. Solids handling, as used in this manual, is a term referring to the wide variety of methods used to treat and dispose of sludge generated from the various unit processes in any sewage treatment plant. Treatment methods include gravity and flotation thickening, chemical conditioning, aerobic and anaerobic digestion, vacuum filtration, sludge drying beds, sludge lagoons, centrifugation, incineration, and wet oxidation. Disposal methods include landfills, ocean disposal, dumping and use as a soil conditioner/fertilizer. Since there are so many different methods in use today, many of which use proprietary equipment having widely varying capacities, this discussion will not deal with each method per se; rather it will provide some general comments on issues common to most solids handling methods and some specific comments on a few methods that are more frequently employed in areas designated as CR areas. Aerobic and anaerobic digestion are exceptions to the above statement and are discussed in detail in a separate section.

WORKSHEET DESCRIPTION

The solids handling worksheet estimates the increases in sludge volumes caused by CR, which in turn indicate the increased solids handling efforts that will be required. The estimated sludge volumes calculated in each process worksheet are summarized in the sludge handling worksheet for easy reference. Comparing the projected sludge volume to typical pre-CR values will determine the approximate increase in equipment operation time and labor necessary to handle the load. Where digestion is used, the total volume is also compared to digester capacities.

WORKSHEET

Solids Handling

Line		Quantity	Units	Line
60	<u>CR Sludge Volumes</u>			
	A. If primary clarifier is a source, enter volume from line 25B here	______	gpd	60A
	B. If trickling filter is a source, enter volume from line 34G here	______	gpd	60B
	C. If activated sludge clarifier is a source, enter volume from line 48D here	______	gpd	60C
	D. Total CR sludge volume: (primary [60A]______) + (trickling filter [60B]____) + (activated sludge [60C]____)	______	gpd	60D
61	<u>Pre-CR Sludge Volumes</u>			
	Average total daily sludge volume produced during typical pre-CR operating conditions (from plant records) =	______	gpd	61
62	<u>Increase in Sludge Volume</u>			
	(CR total volume [60D]______gpd) ÷ (pre-CR total volume [61]_____gpd) =	______	times pre-CR	62

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

A major problem facing the plant operator during CR will be the treatment and disposal of the increased volumes of sludge produced by the various treatment processes. Most of the solids handling problems anticipated during CR will be due to the fact that these activities are very intensive with regard to the use of labor and transport equipment. By estimating the increase in sludge volume, the worksheet provides rough guidelines as to the anticipated increase in labor and operational time for equipment. The best alternative available for dealing with these increased demands is operating the solids handling equipment over increased shifts and for more days per week. To accomplish this might require arranging for relocated personnel to assist in the labor-intensive operations and utilizing unused local transport vehicles to assist in solids or sludge disposal.

If the total sludge volume anticipated during CR cannot be handled with increased operation, the plant operator may have to consider alternative sludge disposal methods. In this case, primary sludge must be given priority in treatment as it represents the greatest problem with respect to pathogenic organisms. An example of an alternative method is to mix untreated secondary sludge with digested primary sludge in temporary lagoons, thus resulting in some degree of treatment. In this situation the sludge lagoon serves partially as an "open air" digester. Lagoons have the advantage that the sludge can be stored indefinitely until conditions return to normal. A further discussion of this option is given in the emergency alternatives portion of the flow reduction section of this manual.

The following troubleshooting guide provides a more detailed description of problems and possible solutions associated with two commonly employed solids handling processes: sludge drying beds and lagoons.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Excessive de-watering time	1a. Applied sludge depth is too great	Any depth greater than 8 inches will hamper drying time.	When bed has dried, remove sludge and clean. Apply a smaller depth of sludge.
	1b. Percent solids too low.	Run jar test on clarifier sludge.	Employ chemical conditioning (alum, ferric chloride, etc.)
	1c. Excessive water in lagoon.	Visual observation	Decant supernatant.
2. Insects breeding		Visual observation, also microscopic observation for fly larvae	Insects may be killed with a suitable insecticide. Ensure an adequate supply is available during CR.
3. Odors when sludge is applied	Inadequate digestion of sludge	Refer to operation of digestion process (troubleshooting guide)	Establish correct operation of digestion process. For temporary control, add lime to sludge. Lime may control odors but may tend to clog sand.
4. Beds undersized for load	Overloaded solids handling	Run jar test on clarifier sludge.	Condition sludges with Polymer. Empty drying beds prior to CR Cover drying beds with glazing (e.g., polyethene sheet, etc.) to speed up process (Be sure to provide good ventilation.)

LABORATORY/PROCESS CONTROL TESTS

The following tests will be most useful during CR to ensure that the solids handling process can be carried out effectively:

1. Total Residue. This test can be used to determine the percent solids of each sludge being applied to solids handling. If the solids become too dilute, operation of clarifiers to produce a thicker sludge will reduce the sludge volume.

2. Jar Test. If chemical coagulants are applied to sludges, a jar test should be run to determine the proper condition for good coagulation of the solids in the process.

3. Microscopic Examination. Fly larvae will be noticeable with examination of a grab sample and insecticides can then be applied prior to the completion of their life cycle.

DIGESTION

PROCESS DESCRIPTION

Sludge digestion consists of biological processes that convert untreated primary and secondary sludges into a relatively inert humus-like material that is less offensive with respect to odor and pathogen content. Digestion reduces the amount of organic solids in the sludge and makes it easier to de-water when applied to drying beds. Anaerobic digestion is the most common method of biological solids treatment but aerobic digestion is commonly found in small package plants. Anaerobic digesters are sensitive to shock loads, changes in temperature, and particularly changes in the hydraulic detention time. If the detention time of an anaerobic digester falls below 12 to 15 days, the system becomes stressed and can potentially fail; and if the detention time falls below 7 days, the digester will fail completely. Aerobic digesters, on the other hand, are very stable and will only experience a gradual decrease in efficiency with the increased loads and decreased detention times during CR. Since anaerobic and aerobic digestion are radically different processes, the remaining discussion in this section is organized around the two processes: pp II-62 to II-65 deal with anaerobic digestion and pp II-66 to II-68 deal with aerobic digestion.

WORKSHEET DESCRIPTION

The worksheet predicts the hydraulic detention time of the anaerobic digester based on the total sludge volume and primary sludge volumes. Line 71 of the worksheet evaluates the impact of the projected detention time.

Line		Quantity	Units	Line
70	<u>Anaerobic Digester</u>			
A.	Digester capacity (applies only to first tank of two-stage digester):			
	diameter of tank = ____ft; height of tank = ____ft;			
	depth of grit layer = ______ft; depth of scum layer ______ft;			
	Capacity of digester in gallons = ______________(Enter on line 70A)			
	If capacity of digester is not known, calculate below:			
	(diameter ____ft) x (diameter ____ft) x (height ___ft - scum layer ___ft -			
	(grit layer ___ft) x 0.785 x 7.48 gal/cu ft =	________	gal	70A
B.	Hydraulic detention time for total sludge production			
	(digester capacity [70A] ____gal) ÷ (total CR sludge [60D] _____gpd) =	________	day	70B
C.	Hydraulic detention time for primary sludge only:			
	(digester capacity [70A] _____gal) ÷ (CR primary sludge [60A] _____gpd) =	________	day	70C
71	<u>Critical Detention Time Check</u>			
A.	Is total sludge volume detention time less than 7 days?			
	Yes: Total sludge volume cannot be treated. Check to see if digester can handle primary sludge volume (line 71C).			
	No: Check line 71B.			
B.	Is total sludge volume detention time less than 12 days?			
	Yes: Possible temporary overload. Monitor digester volatile acids, pH, and alkalinity regularly.			
	No: No operational problems should occur.			

Sludge Digestion (contd)

Line	
71 C.	Is primary sludge volume detention time less than 7 days? Yes: Primary sludge should be treated up to capacity of digester. Efforts should be made to reduce load from community through flow reduction and equalization. No: Check line 71D.
D.	Is primary sludge volume detention time less than 12 days? Yes: Possible temporary overload when treating primary sludge alone. No: Should be able to treat primary sludge successfully.

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE — Anaerobic Digestion

The major problem facing anaerobic digestion during CR will be the increased volume of sludge produced in the primary and secondary treatment processes in response to the increased CR population. This increased sludge volume will require increased sludge pumping which could affect not only the detention time of the sludge but also the temperature in the digester. When the detention time is between 7 to 15 days, the volatile acids begin to accumulate and destroy the natural bicarbonate buffer, leading to a stressed digester. If sufficient bicarbonate buffer (greater than 1,000 mg/l) is not maintained, the digester pH will drop below normal (less than 6.5) poisoning the methane-forming bacteria. This will, in turn, inhibit the gas production and result in the complete failure of the process. A detention time of less than 7 days removes the bacteria faster than they can grow, leading to a rapid, complete digester failure. If sludge pumping exceeds the heating capacity of the digester and the temperature drops, the rates of reaction will decrease, causing symptons similar to an increased loading. Fig. II-10 shows the interrelationships among these factors and how they can lead to potential operational problems or failure of an anaerobic digester.

The following troubleshooting guide provides a more detailed description of various operational problems, their causes, and possible solutions.

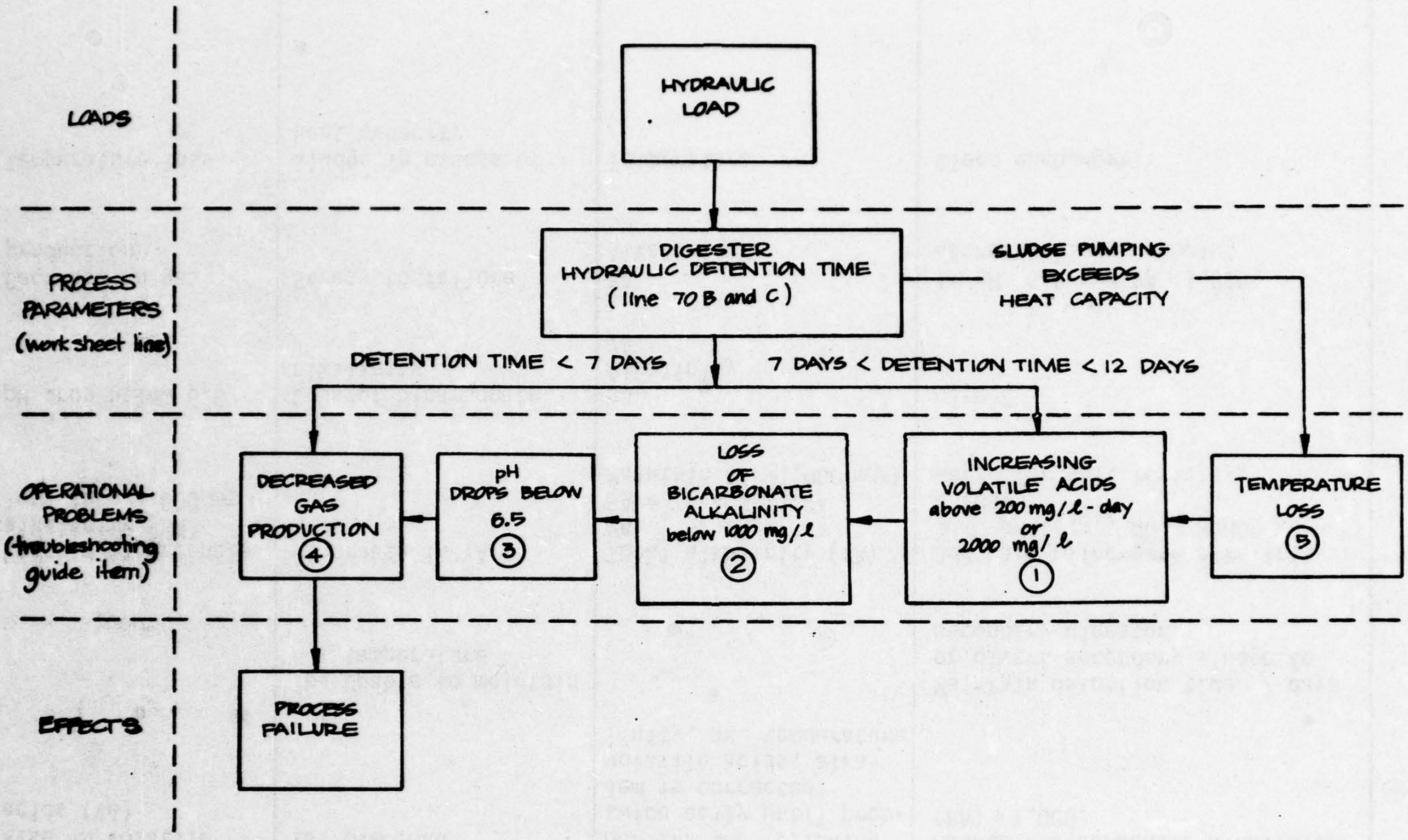


Fig. II-10. Anaerobic Digestion Operational Flow Chart.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Rise in volatile acids (VA)	1a. Overload	Monitor the following twice daily until problem is corrected: volatile acids, alkalinity, pH, temperature	Maintain bicarbonate alkalinity (BA) > 1,000.
	1b. Unable to maintain temperature		Maintain detention time > 7 days or divert secondary sludge to secondary digester.
2. Loss in bicarbonate alkalinity (BA) less than 1,000 mg/l	Increase in VA	Total alkalinity (TA) VA BA = TA - 0.71 VA Maintain BA >1,000 mg/l	Add base to increase alkalinity and pH (e.g., NH_3, $NaHCO_3$, $Ca(OH)_2$. Watch for salt toxicity.
3. pH drop below 6.5	Loss of bicarbonate alkalinity	pH Alkalinity VA	See 2
4. Decrease in gas production	Stress to failure	VA Alkalinity pH	If pH > 6.5 and VA > 1,000, decrease sludge pumping
5. Temperature loss	Sludge in excess of heat capacity	Temperature	Clean exchanger.

LABORATORY/PROCESS CONTROL TESTS—Anaerobic Digestion

Anaerobic digesters should be closely monitored during CR to ensure detection of possible process upsets. The gas production, pH, concentration of volatile acids and the total alkalinity should be measured daily. These tests will be useful in detecting possible upset conditions as follows:

1. Measurement of the alkalinity provides an estimate of the buffer capacity of a digester against an accumulation of volatile acids.

2. Measurement of volatile acids is important because an accumulation of volatile acids will precede a drop in pH. Calculation of the bicarbonate alkalinity

   $$(BA = TA - 0.71\ VA)$$

   will provide a better estimate of the digester's pH stability. The BA should be maintained above 1,000 mg/l.

3. Digester pH should be monitored regularly because the methane bacteria are very sensitive to pH values below 6.5 and a drop in pH below this value will cause process failure.

4. Measurement of the gas production is essential because anaerobic waste stabilization can only occur with gas production. Thus, any decrease in treatment will be reflected in a decrease in gas production.

In addition to these lab tests, measurement of the depth of the grit and scum layers is required to determine the digester capacity in the worksheet.

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE — Aerobic Digestion

Fewer operational problems are associated with aerobic digestion than with anaerobic digestion. The only problems that could occur in the aerobic digester will be a reduction in solids stabilization. Fig. II-11 shows how either an increase in solids loading in excess of aeration capacity or a decrease in detention time can lead to decreased treatment. As a general rule, a complete failure of an aerobic digester rarely occurs.

When an increasing hydraulic load causes the detention time to fall off, a decrease in the volatile solids reduction occurs. As the detention time falls below 10 days, the rate of decrease will be much faster. An increase in the organic load increases the oxygen demand. Should the dissolved oxygen fall below 0.5 mg/l, the decrease in volatile solids will result in decreased treatment efficiency.

Where possible, aeration should continue until the volatile solids are reduced to a level where the sludge is reasonably stable, does not create a nuisance or odors, and will readily de-water.

LABORATORY/PROCESS CONTROL TESTS — Aerobic Digestion

Aerobic digestion efficiency is dependent upon the reduction of volatile solids. To monitor this process, a total volatile solids test must be run. Another important test to be run regularly is the dissolved oxygen content which indicates whether or not the organisms receive a sufficient supply of oxygen to metabolize the volatile solids.

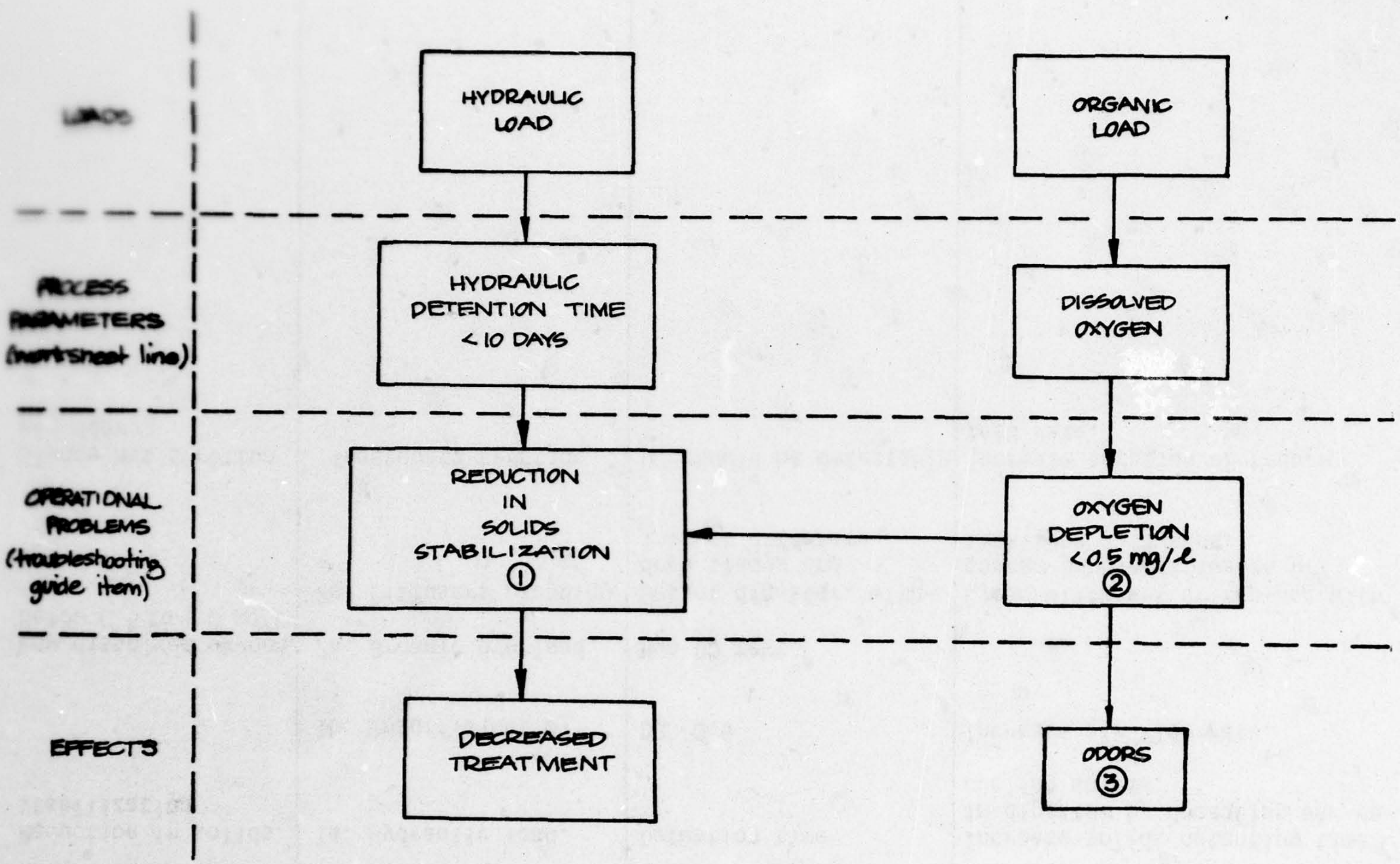


Fig. II-11. Aerobic Digestion Operational Flow Chart.

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Reduction in solids stabilization	1a. Hydraulic load.	Detention time	Increase solids detention time in digester by decanting and recycling solids.
	1b. Insufficient O_2	DO > 0.5	Increase air flow rate.
2. Low dissolved oxygen below 0.5 to 1.0 mg/l	2a. Organic overload	Run DO test	
	2b. Diffusers clogging	Decant digester, withdraw sludge and inspect diffusers	Clean diffusers or replace with coarse bubble diffusers or sock-type diffusers.
3. Sludge has a rotten egg odor	Inadequate aeration	DO should be detectable	Increase aeration or reduce feed rate.

DISINFECTION

PROCESS DESCRIPTION

The primary concern in wastewater treatment, especially during CR, is the prevention of waterborne disease. With the increased population expected during CR there will be a greater demand placed on water and wastewater disinfection. The major disinfecting agents used in wastewater treatment are chlorine (Cl_2) and its derivatives. Because these chemicals have the properties of being strong oxidants, are non-selective microbial poisons, and are easily stored, chlorine finds wider application in wastewater treatment than just disinfection. Some of these uses are the control of odors, corrosion and sludge bulking. The use of chlorine, however, during CR must balance the available supply with the increased disinfectant demand to determine whether these secondary applications should be minimized to conserve the treatment plant's existing supply of chlorine. Thus, this discussion covers the use of chlorine only for disinfection purposes and not for secondary applications. Since it is recognized that chlorine may be in short supply during CR, there is a brief discussion at the end of this section on alternative methods for disinfection.

The use of chlorine as a disinfectant requires applying enough to satisfy the <u>chlorine demand</u> and to produce a sufficient <u>chlorine residual</u>. A portion of the chlorine added to any wastewater is consumed by reactions with various constituents in the waste; the chlorine required to meet these demands is called the <u>chlorine demand</u> and is usually not available for disinfection. The amount of chlorine added over and above these demands is called the <u>chlorine residual</u> and is available for disinfection. The total <u>chlorine dose</u> is the sum of the chlorine demand and the chlorine residual.

Disinfection of wastewaters usually is carried out by mixing the water with chlorine and then holding the chlorinated wastewater in a chlorine contact tank to provide the time required for disinfection prior to discharge. The level of disinfection achieved will increase if either the contact time or chlorine dose is increased. If the current level of disinfection is to be maintained during CR, chlorine consumption will increase during CR because the dosage must be increased to compensate for a decrease in the contact time resulting from the increased hydraulic load and also because there will be more wastewater to treat at that dose. The worksheet for chlorination predicts the chlorine consumption during CR required to provide the same level of disinfection as during pre-CR and calculates how many days supply of chlorine are available to meet this demand.

WORKSHEET

Chlorination

Line		Quantity	Units	Line
80	Contact Chamber Volume			
A.	Rectangular chamber: width = _____ft; length = _____ft; depth = _____ft			
	Volume = (width ____ft) x (length ______ft) x (depth ______ft) x 7.5 gal/cu ft =	______	gal	80A
B.	Circular chamber: diameter = ________ft; depth ____ft			
	Volume = (diameter ___ft) x (diameter ____ft) x 0.785 x			
	(depth ______ft) x 7.5 gal/cu ft =	______	gal	80B
C.	Outfall: diameter = ________inches; length = ______ft			
	Volume = (diameter ______in.) x (diameter _____in.) x 0.0055 x			
	(length ______ft) x 7.5 gal/cu ft =	______	gal	80C
81	Pre-CR Calculations			
A.	Average daily chlorine consumption:			
	(net weight of chlorine cylinder ______lb) ÷ (days used _____) =	______	lb/day	81A
B.	Average chlorine dose based on daily flow and consumption:			
	(consumption [81A] _____lb/day) ÷ (average pre-CR flow [2A] ___mgd) ÷ 8.34 lb/gal =	______	mg/l	81B
82	CR Calculations			
A.	Average chlorine dose required to maintain present level of disinfection:			
	(pre-CR dose [81B] _____mg/l) x (average CR flow [11B] _____mgd) ÷			
	(average pre-CR flow [2A] ______mgd) =	______	mg/l	82A
B.	Average daily chlorine consumption:			
	(average CR flow [11B] ___mgd) x (CR dose [82A] ___mg/l) x 8.34 lb/gal =	______	lb/day	82B

Chlorination (contd)

Line		Quantity	Units	Line
82				
	C. Number of days of chlorine supply:			
	cylinders on hand = ________; net weight per cylinder = _____lb.			
	(number of cylinders___) x (net weight per cylinder ___lb) ÷			
	(CR daily consumption [82B] ________ lb/day) =	________	days	82C
	D. Contact time:			
	(contact chamber volume [80A, B or C] ______gal) ÷ (average CR flow [11B] ____mgd)			
	÷ 1,000,000 x 1440 min/day =	________	min	82D

OPERATIONAL PROBLEMS/TROUBLESHOOTING GUIDE

The operational problems affecting chlorination activities during CR will be directly connected to increased hydraulic and organic loads. Fig. II-12 presents a generalized flow chart of the relationship between various loads, parameters and operational problems. The troubleshooting guide at the end of this section indicates specific problems, indicators, and possible solutions.

Theoretically the same level of disinfection can be obtained for different combinations of contact time and chlorine residual as long as the product of the two remains relatively constant. Since the contact time, which is essentially a detention time, may decrease during CR due to the increased hydraulic load, the same level of disinfection can be provided by increasing the residual. However, since more chlorine will be required during CR to provide the same level of disinfection and since it probably will be in short supply due to other competing demands, a minimum contact time of about 15 minutes should be strived for to achieve adequate mixing and dispersal and then only enough chlorine should be applied to achieve the required chlorine residual.

As a general rule, it has been found that improved mixing and longer contact times are more effective than increased chlorine dosage in providing the same level of disinfection. Thus any actions, such as installing baffles, mechanical mixing, or air agitation, which will either increase the contact time or the mixing, should be preferred over increased chlorine dosages. The troubleshooting guide provides a more detailed description of some of these problems and possible solutions.

Because the length of the CR period is somewhat uncertain, it will be

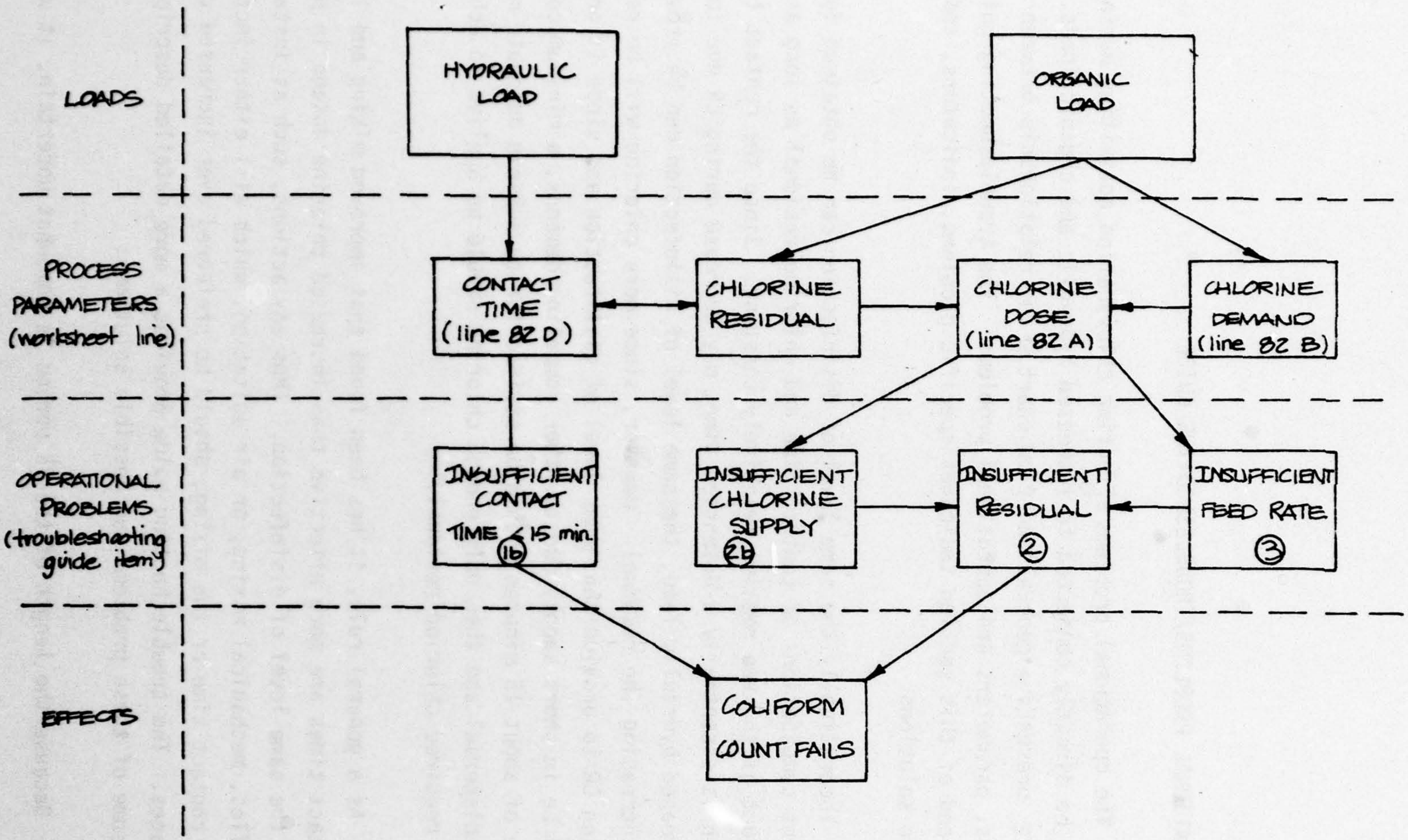


Fig. II-12. Chlorination Operational Flow Chart.

most important to try and maintain some level of disinfection throughout the entire CR period. If the supply of chlorine is not sufficient to maintain the normal level of treatment and additional supplies or other chemicals are unattainable, the chlorine feeder rate should be decreased to extend the supply. However, before this action is taken, local health and water quality regulatory personnel should be contacted, particularly if downstream uses of the receiving water include human contact or consumption.

TROUBLESHOOTING GUIDE

Chlorination

INDICATORS/OBSERVATIONS	PROBABLE CAUSE	CHECK or MONITOR	SOLUTIONS
1. Coliform count fails to meet required standards for disinfection	1a. Cl_2 residual too low	Cl_2 residual	Increase feeder rate
	1b. Contact time less than 15 min.	Worksheet Line 82D	Install baffles, mechanical mixing or air agitation. Flow reduction Flow equalization Clean out solids buildup in contact chamber.
2. Residual too low < 0.5 mg/l after 15 minutes	2a. Insufficient dose	Cl_2 residual	Increase dose
	2b. Insufficient supply	Worksheet Line 82C	Increase stockpile of Cl_2 or use other disinfectants
	2c. Insufficient feeder rate	See 3	See 3
3. Insufficient feeder rate	Insufficient evaporator capacity	Visual inspection; also icy to the touch	Place heat lamps on feeder system

LABORATORY/PROCESS CONTROL TESTS

The two standard tests for determining adequate levels of disinfection are the orthotolidine chlorine residual and the total coliform MPN tests. Disinfection is assumed to be adequate if sufficient chlorine is added such that a residual of 0.5 ppm is present 15 minutes after the chlorine is applied. This can be rapidly determined by the orthotolidine chlorine residual test. It is important, especially during CR, that this test be performed on samples taken during the peak flows. However, it is possible that the above residual will not meet the local disinfection standard which in many cases is 100 coliform bacteria per 100 ml. This can only be determined by the MPN test *which unfortunately requires over two days to perform.* Thus, this test is not useful for daily operational control. During CR, the MPN test should be conducted during the relocation buildup to assess how the increased load is affecting the coliform count. If it still is within the locally established limits, then the chlorine residual test can be used to daily monitor the disinfection operation. If not, then steps must be taken to rectify the situation.

It should be noted that the chlorine dose necessary for adequate disinfection will vary widely with the character of the waste, temperature, pH, and numerous other factors that cannot be controlled by the plant operator. For this reason it will be particularly important to continuously monitor effluent quality to determine the level of disinfection.

ALTERNATIVE DISINFECTION METHODS

Other disinfection methods exist as alternatives to chlorine such as ozone, bromine, iodine, and ultraviolet. However, all of these alternatives either require specialized equipment, an energy source, or are significantly more expensive. Nevertheless, it is recognized that chlorine may be in short supply during CR, thus necessitating the use of other disinfectants. This section briefly describes some of the other chemical disinfectants while recognizing that their availability in any particular area during CR may be as uncertain as chlorine. Efforts should be made to identify local sources of supply of other chemical disinfectants prior to CR so that they can be rapidly obtained if chlorine supplies become critical.

1. Sodium Hypochlorite (NaOCl). The disinfection potency of 1 mg/l of chlorine from sodium hypochlorite is just as effective as an equivalent amount derived from liquefied chlorine gas. With the exception of the feeder, storage and some piping, a hypochlorination system is very similar to one using liquid chlorine. The availability of sodium hypochlorite should be essentially the same as chlorine. Both are produced by essentially the same process.

2. Bromine Chloride. Bromine chloride has similar germicidal qualities to chlorine. However, bromines are less stable in water and break down to form bromine salts. Existing chlorination facilities would require only minor modifications to convert from chlorine to bromine chloride. As of 1976, there were only three manufacturers of bromine chloride and its supply was limited.

3. Chlorine Dioxide. Chlorine dioxide is a powerful oxidizing agent and an excellent disinfectant; however, it is unstable and extremely corrosive. The lack of an adequate method for accurately determining low residual concentrations is a serious drawback. Because it is a strong oxidizing agent, more chlorine dioxide than chlorine may be required to achieve the same level of disinfection.

4. Lime at pH of 11 or higher. Even in the presence of relatively high concentrations of organic matter and under the adverse conditions of low temperature sewage can be disinfected to a safe level by lime treatment of pH 11.5 or 12.0. The process of disinfection can be completed within a relatively short time period (30 minutes or less), even at 1°C. Lime treatment also involves the reduction of organic materials and phosphorus which will increase the amount of sludge that will eventually need to be disposed of.

5. Bromine. Bromine is a good germicidal agent and effective tests are available for determining residual concentration. Bromine, hypobromous acid (HOBr), and monobromamine are considered nearly equal in bactericidal properties and essentially equal to free chlorine at comparable pH.

6. Low pH as a Disinfectant. Exposure of micro-organisms to extremes in hydrogen ion concentration is a relatively ineffective method of disinfection, since enteric bacteria must survive the extreme acid pH of the stomach before entering the small intestine. Thus, for low pH to be a truly effective disinfectant, extreme acidity must persist for a considerable period of time.

SUMMARY OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

Each process discussion has identified the parameters which are key to the efficient operation of that process and which most likely would be affected by conditions associated with CR. As noted, some processes are more sensitive than others to overloading conditions anticipated during CR; a few processes may actually fail altogether if the value of a particular parameter exceeds a critical value. The Summary Sheet summarizes the following information for each process:

1. Key process parameters.
2. Critical values for the key process parameters.
3. Generalized effect if the value of a key process parameter exceeds its critical value. These generalized effects are categorized as follows: failure, possible failure, decreased treatment, and nuisance.
4. Actions recommended depending on the severity of the generalized effect. These actions are categorized as follows:
   a. Avoid at all costs — process failures should be avoided at all costs since they will significantly affect the treatment capability of a plant and could lead to severe public health problems.
   b. Intensive control — potential process failures need to be closely monitored and require whatever actions necessary to prevent the process from reaching a failure condition.
   c. Consult regulatory agency — the effects of decreased

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EMERGENCY SEWAGE PROCEDURES DURING CRISIS RELOCATION.(U)
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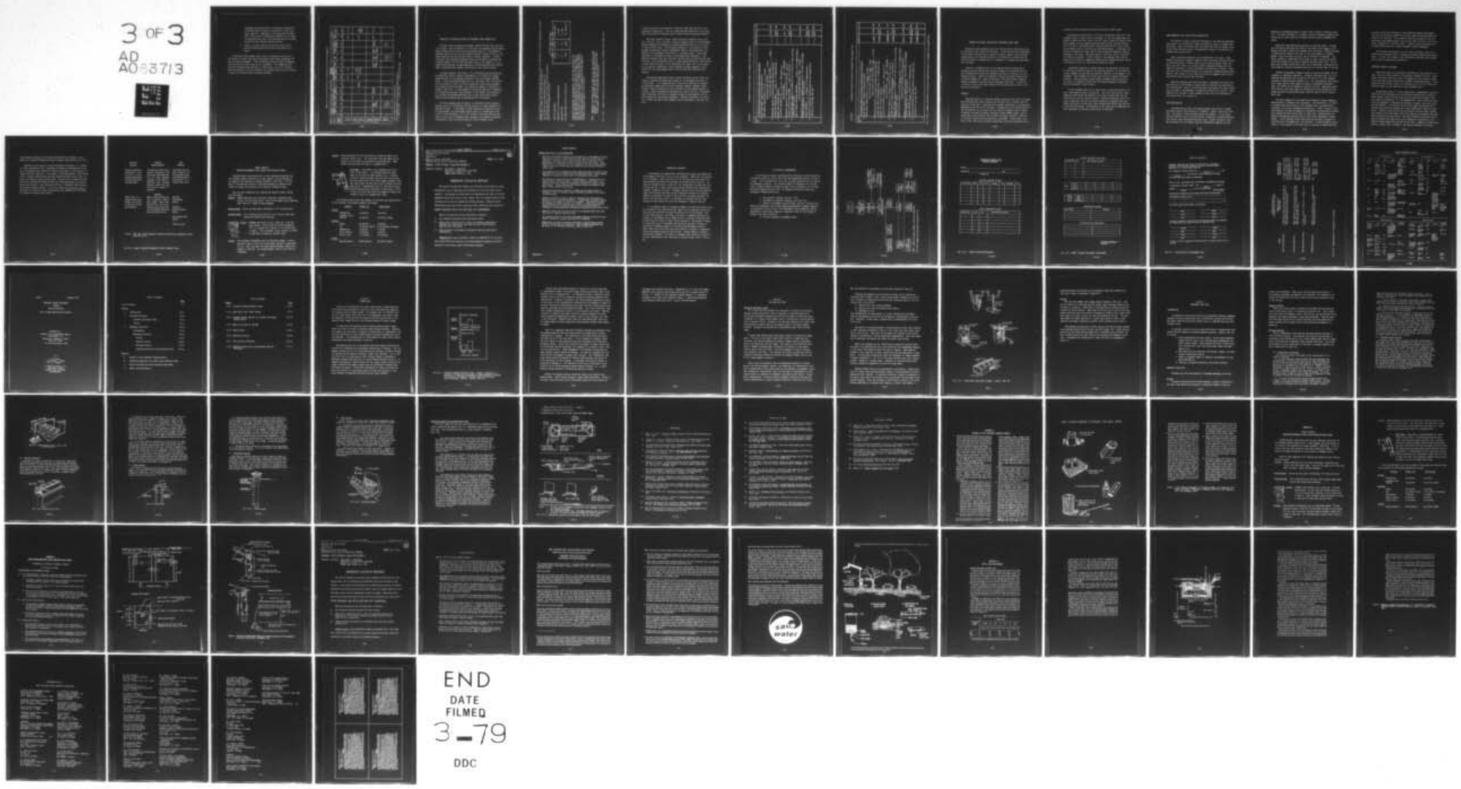

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treatment which could lead to a substantial degradation of effluent quality should be explored with local regulatory agencies. Depending on the nature and the magnitude of the effect of decreased treatment and its impact on downstream water uses, this condition may be tolerable during CR or may require corrective action.

d. Ignore — nuisance effects do not pose serious public health problems during CR and thus can usually be ignored.

At the top of the summary sheet, space is provided for the user of this manual to insert the values calculated on each process worksheet for the key process parameters. These calculated values can then be compared with the critical values shown on the worksheet. This comparison will allow the treatment plant operator, or CRP planner, to tell at a glance where the potential critical problems exist and what type of actions should be taken to deal with these anticipated problems.

SUMMARY SHEET OF CRITICAL PROCESS VALUES, THEIR GENERALIZED EFFECTS AND ACTIONS RECOMMENDED

PROCESS →		PRIMARY	TRICKLING FILTER		ACTIVATED SLUDGE			ANAEROBIC DIGESTION	PONDS		LAGOONS		CHLORINATION	
PARAMETER →		HYDRAULIC OVERFLOW RATE	ORGANIC LOADING	CLARIFIER OVERFLOW RATE	EXCESS AERATION CAPACITY	F/M RATIO	CLARIFIER OVERFLOW RATE	HYDRAULIC DETENTION TIME	DETENTION TIME	BOD LOAD	DETENTION TIME	EXCESS AERATION CAPACITY	CONTACT TIME	Cl_2 SUPPLY
CALCULATED VALUE → Worksheet Line :		22B	32E	34C & D	47F & G	46	48A & B	70B	55E	55C	55E	58F	82D	82C
GENERALIZED EFFECTS: FAILURE	1*						> 1200	< 7 days					< 5 min.	< 5 days
GENERALIZED EFFECTS: POSSIBLE FAILURE	2*				< 0	> 0.5 Bulking	> 800	> 7 days < 12 days (stressed)					< 10 min	< projected CR duration
GENERALIZED EFFECTS: DECREASED TREATMENT	3*	>1200	gradual (see work-sheet)	>1200	approaching zero				gradual (see work-sheet)	gradual (see work-sheet)	gradual (see work-sheet)	approaching zero	< 15 min	< 60 days
GENERALIZED EFFECTS: NUISANCE	4*		odors increased values		possible odors					odors at higher loads		odors at < 0		

NOTE: An empty box denotes no significant problems.

* ACTIONS RECOMMENDED DEPENDING ON THE SEVERITY OF THE GENERALIZED EFFECT:

1. AVOID AT ALL COSTS 2. INTENSIVE CONTROL 3. CONSULT REGULATORY AGENCY 4. IGNORE

PROJECTED CR POPULATION BASED ON TREATMENT PLANT CAPABILITIES

The data from the completed worksheets should give the plant operator, or CR planner, some indications as to the level of treatment and the approximate effluent quality that would be expected during CR. The summary of worksheet values can be used to determine potential process failures or effluent quality which may not meet state or Federal standards. In these situations local regulatory agencies should be consulted to evaluate the projected effect of CR on receiving water quality, the impacts of a degraded receiving water on downstream users, and the measures that could be taken to minimize these impacts, particularly public health impacts.

For many potential host sites, it is anticipated that the projected CR population, based on shelter requirements, will exceed the maximum population that can be adequately served by the local sewage treatment plant. If the projected CR population for a particular host site results in one or more of a plant's critical operational values being exceeded, one solution available to DCPA is to reduce the number of relocatees assigned to that area. For the purpose of providing additional information to CR planning personnel, the worksheets in this manual can be modified to calculate the maximum population that a plant could safely handle. There are two different ways of approaching this calculation.

The first approach uses the manual as written and involves making a parallel series of calculations for each process for lower projected CR population values. If the range of lower projected CR population values is broad enough, the calculations should result in a bracketing of the critical value parameters. Fig. II-13A briefly illustrates how the worksheets can be used to determine what percent of the original projected CR population could be safely served by a local treatment plant.

Example calculation of clarifier overflow rate for initial host population of 38,000; average flow of 2.3 mgd; and activated sludge final clarifier area of 6400 sq ft

(pre-CR overflow rate approximately 360 gpd/sq ft)

CR projected population is five times initial host population based on available congregate care space.

	CR Projected Population 100%	80%	60%
Total CR population	190,000	152,000	114,000 people
Additional CR flow at 50 gpd/relocatee	7.6	5.7	3.8 mgd
Average CR flow	9.9	8.0	6.1 mgd
Activated sludge clarifier overflow rate	1,546	1,250	953 gpd/sq ft

From these calculations, the maximum population for this relocation site should be approximately 150,000 people, a four-fold increase, based on a maximum clarifier overflow rate of 1200 gpd/sq ft as shown on page 82. Thus, the five-fold CR projected increase in population based on shelter space will result in hydraulic overload to clarifier and eventual failure of the activated sludge process. This assumes that the host community continues to generate sewage at its pre-CR rate.

Note: Comparable calculations should be made for the other activated sludge parameters (i.e., 90A and 90E) and the smallest population increase selected. This approach will give the limiting CR population based on the "weakest link" in the activated sludge process.

Fig. II-13A. Example Calculation of Limiting CR Population Based on Treatment Plant Capabilities.

A parallel series of calculations is done for 100%, 80%, and 60% of the projected CR population. Then, an interpolated CR population can be found which just gives the threshold value of each critical operating parameter.

The other approach involves identifying each treatment process that has a critical value, and then, using the formulas given in the worksheets, working backwards to determine a maximum population that will just result in that critical value. The following worksheet is illustrative of how a maximum CR population could be determined, based on the operational limitations of one treatment plant process — activated sludge. The maximum population is evaluated in terms of three operational parameters: the aeration capacity; the final clarifier overflow rate; and the aeration tank F/M ratio. The calculations result in three population values, the smallest of which should be used, as this represents the "weak link" in the system. Fig. II-13B uses information in this worksheet to make comparable calculations for the same example given in Fig. II-13A, which used the first approach.

Projected CR populations much in excess of these critical values will indicate a potential problem with respect to the treatment efficiency of a local plant. It is recognized that it may not be possible to allocate CR populations based solely on plant capacity; however, attempts should be made to keep increases as close as possible to the maximum capacity of a plant. Excessive population overloads will result not only in decreased plant efficiency, but also in a marked increase in the potential for disease transmission and possible epidemics. Another alternative, of course, is to reduce the load on the treatment plant as discussed in the next section.

WORKSHEET

Projected CR Population Based on Treatment Plant Capabilities

Line		Quantity	Units	Line
90	CR Population Based on Activated Sludge Process Limitations			
A.	Excess BOD removal capacity at maximum aeration (BOD removal capacity [47B or D or E] ________ lb/day) - (pre-CR plant BOD load [4C] ________ lb/day - pre-CR primary BOD removal [24D] ________ lb/day) =	________	lb/day	90A
B.	Relocation capacity as limited by maximum aeration capacity: (excess BOD removal [90A] ________ lb/day) ÷ 0.1 lb BOD/person-day =	________	extra people	90B
C.	Excess final clarifier capacity: (clarifier area [42A or B] ________ sq ft) x 1200 gpd/sq ft) - (pre-CR flow [2A] ________ mgd x 1,000,000) =	________	gpd	90C
D.	Relocation capacity as limited by final clarifier capacity: (excess clarifier capacity [90C] ________ gpd) ÷ 50 gpd/person =	________	extra people	90D
E.	Excess BOD removal capacity as related to F/M ratio and the final clarifier maximum solids loading: (mass of MLVSS in aeration tank [45B] ________ lb/day x 0.45 lb BOD/lb MLVSS) - (pre-CR primary BOD removal [24D] ________ lb/day) =	________	lb/day	90E
F.	Relocation capacity as limited by aeration tank F/M ratio, and maximum solids loading rate in final clarifier: (excess BOD [90E] ________ lb/day) ÷ 0.1 lb BOD/person-day =	________	extra people	90F
G.	Limiting CR population increase based on plant capabilities: smallest of Lines 90B, 90D, 90F =	________	extra people	90G

WORKSHEET

Projected CR Population Based on Treatment Plant Capabilities

Line		Quantity	Units	Line
90	CR Population Based on Activated Sludge Process Limitations			
A.	Excess BOD removal capacity at maximum aeration (BOD removal capacity [47B or D or E] 15,000 lb/day) - (pre-CR plant BOD load [4C] 5195 lb/day - pre-CR primary BOD removal [24D] 1818 lb/day) =	11,623	lb/day	90A
B.	Relocation capacity as limited by maximum aeration capacity: (excess BOD removal [90A] 11,623 lb/day) ÷ 0.1 lb BOD/person-day =	116,230	extra people	90B
C.	Excess final clarifier capacity: (clarifier area [42A or B] 6400 sq ft) x 1200 gpd/sq ft) - (pre-CR flow [2A] 2.3 mgd x 1,000,000) =	5,390,000	gpd	90C
D.	Relocation capacity as limited by final clarifier capacity: (excess clarifier capacity [90C] 5,390,000 gpd) ÷ 50 gpd/person =	107,800	extra people	90D
E.	Excess BOD removal capacity as related to F/M ratio and the final clarifier maximum solids loading: (mass of MLVSS in aeration tank [45B] 99,840 lb/day x 0.45 lb BOD/lb MLVSS) - (pre-CR primary BOD removal [24D] 1818 lb/day) =	43,110	lb/day	90E
F.	Relocation capacity as limited by aeration tank F/M ratio, and maximum solids loading rate in final clarifier: (excess BOD [90E] 43,110 lb/day) ÷ 0.1 lb BOD/person-day =	431,100	extra people	90F
G.	Limiting CR population increase based on plant capabilities: smallest of Lines 90B, 90D, 90F =	107,800	extra people	90G

Fig. II-13B. Example Calculation of Limiting CR population Based on Treatment Plant Capabilities.

METHODS FOR OVERALL REDUCTION OF TREATMENT PLANT LOADS

During CR, many treatment plants will not be able to effectively process the entire load coming into the plant. If the results of the worksheets in this manual indicate that a hydraulic, organic, and/or solids overloading may cause severe problems during CR, an alternative to processing the entire CR load at a reduced level of treatment is to reduce the load coming into the plant.

Loads on a treatment plant can be reduced either by decreasing or eliminating wastes entering the collection system or by diverting part of the collected waste around the treatment plant by an intentional or unintentional bypass. Some of the methods of controlling wastes entering the collection system are: water conservation, flow equalization, temporary industry shutdowns, and provision for emergency facilities. A brief description of each of the above methods for load reduction is given in this section of the manual.

BYPASSES

Bypassing refers to a condition where a portion of the load is diverted away from the plant usually because the influent load is greater than the capacity of the plant. Bypassing can be either intentional or unintentional depending on how the flow is diverted. Although Public Law 92-500 prohibits the discharge of any pollutant into the nation's navigable waters without a National Pollutant Discharge Elimination System (NPDES) permit, and although many states prohibit the existence of bypass structures, there may be situations during CR when bypassing is advisable. Should these situations arise, local water pollution authorities should be contacted and the

situation closely monitored to minimize the public health hazard.

Unintentional bypassing will occur when the hydraulic capacity of the treatment plant or sewer system is exceeded. If the raw sewage pumps are unable to handle the flow, sewer lines will begin to back up, manhole covers may be popped, and raw sewage could then begin to flow into the streets. This will pose a significant public health problem and will require immediate attention such as installing an intentional bypass. If the pumps are capable of handling the flow, but the flow exceeds the hydraulic capacity elsewhere in the plant, individual process facilities within the plant will begin to overflow. In this situation, the operator could divert a portion of the flow to a temporary holding basin, sandbag the walls of the overflowing facility, or intentionally bypass the plant.

Intentional bypassing is usually done at the head works of the process and can be directly passed to the receiving water or to the chlorine contact chamber provided that the hydraulic capacity in the chamber is not exceeded. Some treatment facilities may be set up to bypass individual processes. Where possible, primary sewage treatment should be given to all flow in an attempt to settle out the large percentage of pathogens which are harbored in these solids.

If the treatment plant has no bypass lines, it may be possible to install some temporary means of bypassing. This could involve some major temporary construction and temporary pipe lines to divert the flow for chlorination or to the receiving waters. Another alternative would be to place a sump pump into the last manhole before the treatment plant and divert the flow to a storm drain, thus allowing the flow to move directly to the receiving waters. Disinfection at this point may be impossible unless some means for portable chlorination is available.

HOME/CONGREGATE CARE CENTER WATER CONSERVATION

The practice of water conservation measures in the home and congregate care centers can significantly reduce the hydraulic load on a sewage treatment plant. Water conservation does not affect the solids or organic load so that flow reduction causes a corresponding increase in the BOD and suspended solids concentration.

Water conservation measures can be categorized in two ways: those measures relying on a change in people's water use habits and those relying on installed devices. Measures that rely on changing people's water use habits not only require an extensive public education program but their degree of acceptance is highly problematic and difficult to predict. Measures that rely on installed devices are continuously effective once installed; however, their impact on flow reduction is heavily dependent both on their availability and on having them installed.

Water has multiple uses within the home or congregate care center and each use has its own methods of conservation to minimize the health hazard and inconvenience. Ways of instituting water conservation for some of these uses are given in two pamphlets included at the end of this section. These pamphlets are included as sample pamphlets which could be reproduced and distributed prior to or during CR.

FLOW EQUALIZATION

Flow equalization refers to methods designed specifically to dampen the normal diurnal flow variations in hydraulic, organic, and solids loadings. The benefits from flow equalization are numerous. It can reduce the peak overflow rates in settling basins, resulting in improved efficiency and possibly fewer disruption from peak flows. Aerobic biological treatment processes can also benefit from the concentration damping and flow

smoothing by eliminating peaks in organic load in excess of aeration capacity. Its major advantage is to protect sensitive treatment processes from failure due to shock loads and to improve overall process treatment efficiency.

During CR, flow equalization measures can take two forms: (1) measures directed at modifying the timing of the loads at the source, or (2) measures directed at modifying treatment plant operations. Measures directed at modifying the timing of the loads at the source depend on changing people's water use habits and thus, may be difficult to implement. The hourly variation in home water use by type of water use can vary widely. Plant flow records can be used to identify the peak hourly flow. If the major uses of water during these times can be identified, then efforts can be directed at trying to encourage these uses at low-flow times of the day.

Efforts to encourage a change in water use habits can either rely on voluntary or regulatory compliance. Voluntary compliance must rely on information dissemination and can exploit the "we're all in this together attitude" by getting people together (e.g., at a town meeting) and conducting a rough survey of when people use water, to determine how people's water use habits can be changed to equalize the flow. Regulatory compliance involves using some scheme for dividing up the host population into groups and then assigning each group a specific time of day for various water uses.

The other category of flow equalization measures involves temporary modifications to treatment plant operations. One alternative is to build an earthen equalization basin at the treatment plant, provided land is available, or to use an abandoned existing basin. Flows in excess of the plant capacity can then be temporarily diverted to this basin and re-diverted back through the plant during times of lower flow. Earthen basins are generally inexpensive and can be built with a basic knowledge of lagoon design. For CR, the most useful basin would be one that is placed as a side-line unit (as opposed to an in-line unit). A side-line basin can be smaller in size than an in-line one since it only has to handle the flow

in excess of the daily average; it also minimizes pumping requirements. With the utilization of equalization basins, pumps and above-ground pipelines will be required. Also, aeration should be provided to keep the wastewater from becoming septic; this will be more critical in an in-line basin as opposed to a side-line basin. Finally, gravity discharge from an equalization basin will require automatic control regulators.

Still another alternative is to use large interceptor sewer lines entering the treatment plant for temporary storage to dampen peak diurnal flows. If used in this manner, the interceptor system may need flushing out of solids accumulation periodically.

TEMPORARY INDUSTRY SHUTDOWNS

Industrial wastes are often major contributors to the hydraulic, organic and solids loads handled by a wastewater treatment facility. Under severe overloading conditions, mutual arrangements could be made to temporarily shut down certain industries to reduce overloading problems. Thus, industrial contributions need to be inventoried prior to CR to assess the potential impact on the operations of the treatment plant.

For most host areas, it is anticipated that a comprehensive record of industrial waste discharges will be available from historical records of sewer charges. When existing records are not available to assess industrial waste contributions, it is recommended that a rapid industrial waste survey be conducted to determine the hydraulic, organic, and solids load for each industry. Carrying out such a survey under the pressure of CR requires some innovation compared to a more conventional industrial waste survey. Hydraulic contributions may be obtained from past water consumption records, while the organic and solids load can be estimated from laboratory analysis from each source. Two rapid laboratory tests that can be used to estimate the organic and solids loading are, respectively, the Chemical Oxygen Demand and the total solids tests. Samples for these tests should be grabs taken throughout the day and combined to provide a

representative composite of the waste generated by the industry. An example of an industrial/commercial waste inventory form is given in Fig. II-14.

Depending on the nature of the anticipated CR overloads (i.e., hydraulic, BOD, suspended solids) a knowledge of industrial contributions can be used to determine which industries should be shut down, if this measure is deemed absolutely necessary. For example, if BOD overloading is anticipated to be a problem, shutting down any meat processing plants will be very effective in reducing industrial BOD loads. The decision to temporarily shut down certain industries should be taken only after deliberate consultation among city officials, local regulatory officials, treatment plant operators and affected industry leaders. Priorities should be established based on the nature of industrial waste contributions, the importance of the industry during CR and many other factors.

Name and Location	Industrial Waste Description	Key Personnel
Industries should be in alphabetical order. Location should include manhole where industrial waste enters municipal system.	List waste by common name, chemical nomenclature, and trade name, if applicable. Also list any other hazardous materials on hand that can potentially enter municipal treatment system and give neutralizing agents, if applicable.	*Give names, titles and phone numbers of all* key personnel. At least one number should be designated as a 24-hour a day number.
	SAMPLE	
ACME Mfg. Co. – Industrial waste is discharged into manhole at intersection of Main and Pine Streets.	Waste is acidic, pH below 4.0 due to presence of sulfuric acid, H_2SO_4. There exists potential for a spill of concentrated sulfuric acid which can be neutralized with strong basic materials such as lime.	John Doe *Plant Manager* (phone) Bill Smith Maintenance Supt. (phone) Plant Security Office (phone)* *24-hour number

Source: EPA, Feb. 1974, Emergency Planning for Municipal Wastewater Treatment Facilities.

Fig. II-14. Sample Industrial/Commercial Waste Inventory Form.

Sample Pamphlet

HOUSEHOLD/CONGREGATE CARE CENTER WATER REDUCTION IDEAS

Household water conservation will be very important during CR, not only because potable water may be in short supply, but also because of its impact on the operation of sewage treatment facilities. A lot of water in the home may be going to the sewer needlessly, adding to the volume of sewage and putting an extra burden on treatment plants.

Here are some suggestions for reducing the amount of water flowing into the sewers.

Bathing — Showers generally use less water than baths, especially when using a low-flow shower head. Turn off the shower while lathering; then rinse off. Bathe children together.

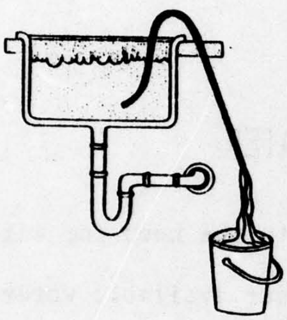
Washing Hands — Do not run the faucet continuously; fill the wash basin.

Brushing Teeth — Fill a drinking glass and use it for rinsing rather than running the faucet while brushing.

Toilets — Remember the toilet is not a trash can — use the waste basket. Do not flush the toilet needlessly ("If it's yellow-let it mellow, if it's brown-flush it down"). Place weighted plastic bottles or bricks in the tank to reduce the flow per flush.

Kitchen — With automatic dishwashers only run when fully loaded. If hand washing is done, a sink full of wash water and one of rinse water will do. Don't let water run when washing produce; rather put a stopper in the sink. For drinking water, store a jug in the refrigerator.

Laundry Washing machines use 40 to 50 gallons of water per wash so be sure each load is full. The rinse water from the washer can be ponded in a wash basin and diverted for grey water use. Hand washed clothing should be done in a stoppered basin.



Grey Water Grey water is any wastewater not originally in the toilet. If collected during CR, grey water can be used for other purposes (e.g., flushing toilets or watering plants) thus not only saving water but also reducing the flow to the sewage treatment plant. The figure shows how grey water can be siphoned from any water basin. Alternatively, the "P" trap can be disconnected allowing direct collection of grey water (if this is done, the drain pipe should be capped to prevent overflowing in case of a plugged sewer line).

The following table cites some examples of the water use reduction that can be achieved in the home/congregate care center.

	Examples	Normal Use	Conservation
Kitchen			
	Dishwashing	30 gallons	5 gallons
	Automatic dishwashing	16 gallons	Use fully loaded
Bathroom			
	Shower	25 gallons	4 gallons
	Tub	36 gallons (full)	10-12 gallons (minimum)
	Handwashing	2 gallons	1 gallon
	Teeth brushing	10 gallons	½ gallon
	Toilet flush	5-7 gallons	4-6 gallons
Laundry			
	Washing machine	40-50 gallons	Use fully loaded

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY Sample Pamphlet EDMUND G. BROWN JR., Governor

DEPARTMENT OF HEALTH
2151 BERKELEY WAY
BERKELEY 9470-

PUBLIC HEALTH DIVISION
ENVIRONMENTAL HEALTH SERVICES BRANCH

APRIL 27, 1977

DROUGHT INFORMATIONAL BULLETIN NUMBER 1

CONTACT PERSON: WILLIAM F. JOPLING
SANITARY ENGINEERING SECTION
(415) 843-7900 EXT. 413

INFORMATION CIRCULAR ON GREYWATER

The current drought has brought much attention to the need for water conservation and is requiring more efficient use of our available water supplies. Many groups and individuals are advocating the reuse of certain household wastewaters such as sink, shower, tub, or laundry washwaters for flushing toilets and for irrigation outside the home. These household wastewaters other than toilet wastes are often referred to as "greywater." Toilet wastewater must not be used under any circumstances.

The use of greywater may be considered as follows:

1. **As a temporary measure during the water crisis;**
2. **Where water shortages exist, where all possible conservation measures have been taken, and where no other water is available for home irrigation;**
3. **After approval and guidance is obtained from the local health jurisdiction.**

Indiscriminate use of greywater cannot be condoned for it has long been established that greywater can create numerous nuisance conditions and may be a potential source of waterborne disease.

Sample Pamphlet

Recommended Practices and Procedures

- The only recommended interior use of greywater is the dumping of bath water, dish water, or sink water directly into the toilet bowl for flushing. Greywater can be placed in the toilet tank only after physically disconnecting the water inlet pipe to the toilet. This must be done if greywater is to be placed in the toilet tank because a drop in pressure could draw the greywater back into the domestic water lines.

- Any modifications to plumbing systems should be done only after being approved by the local health and building authorities. The plumbing should be returned to normal after the emergency has passed.

- The storage of greywater must be accomplished in a manner that will minimize the problems of odors, vermin, insects, and safety. All storage containers should be screened or covered to exclude rodents and insects. Large containers may become attractive nuisances and pose a safety hazard to children.

- Grease and food scraps should be scraped off of dishes prior to washing in order to minimize insect and odor problems if this water is to be reused.

- Outside irrigation should be done in a manner that will minimize possible health risks and nuisances. Irrigation by greywater should not result in ponding or runoff of the water. This can be avoided by constructing berms around trees, shrubs, or plants and assuring rapid percolation by utilizing gravel or other porous material. Irrigation through perforated underground irrigation pipe is preferred.

- Greywater should not be used on root or low-growing food crops that will come in contact with the water.

- If a family member is ill from a diarrheal disease, do not use their shower, bathtub or laundry greywater for irrigation.

- Homeowners are urged to contact gardening or agricultural experts prior to irrigation with greywater. Many household chemicals may be toxic to, or otherwise adversely affect, vegetation.

MECHANICAL EQUIPMENT

The worksheets and operational troubleshooting guides have emphasized the treatment efficiency of the various processes. During CR, the capacity of all equipment within the plant will be utilized more than normal and some equipment may need to be operated at maximum possible capacity. Mechanical equipment within a plant will also experience increased uses (eg., 24 hours per day, 7 days a week) during CR and therefore may undergo more frequent mechanical failures. Equipment failure during CR can potentially cause more problems than during pre-CR conditions because the increased demands on equipment will make it more difficult to bypass equipment for repairs and servicing. Thus it is advisable to minimize both the time required to make repairs and also the frequency of repairs during CR.

If an adequate supply of frequently needed or difficult-to-obtain parts are available at the plant during CR, repairs can be made more rapidly because the time required for order and delivery will be eliminated. Also if sufficient warning is available, any parts or equipment scheduled for overhaul or replacement can be tended to prior to actual relocation thereby minimizing the chance of their failure during CR. One potential method of identifying parts or equipment that should be serviced, replaced, or maintained in adequate supply is to review plant maintenance records. Those items that historically have been difficult to obtain or frequently require replacement should be kept on hand. Another method of identifying possible problems is to check for equipment that recently has begun to "act up" manifested by such indicators as unusual noises, erratic service, etc.

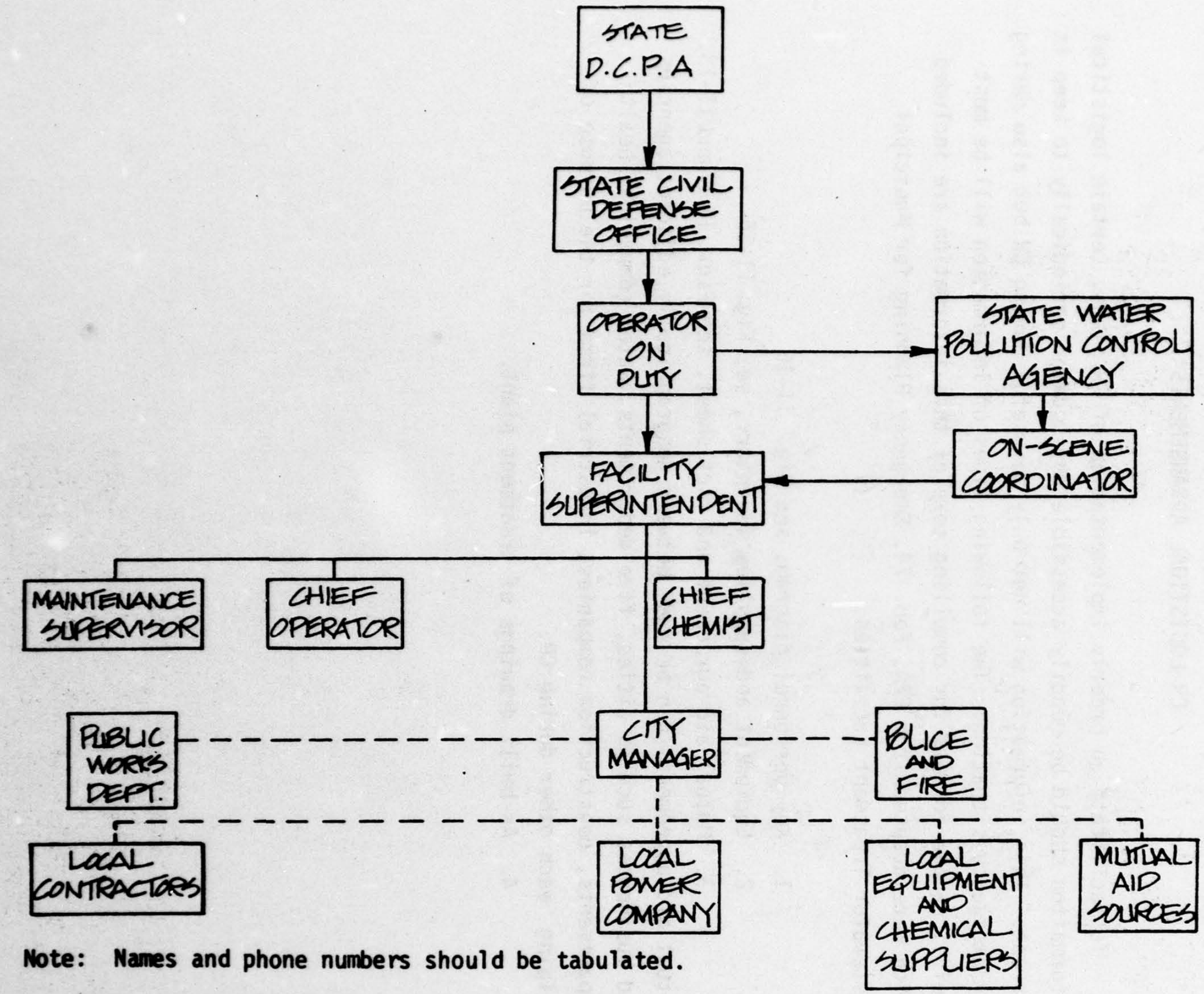
CR LOGISTICAL ARRANGEMENTS

To facilitate an orderly implementation of CR plans, certain logistical information should be readily accessible and updated periodically to keep it current. This information will not only be useful during CR but also during any emergency situation. The following types of information will be most useful; sample formats for compiling some of this information are included which were adapted from EPA, Feb. 74, Emergency Planning for Municipal Wastewater Treatment Facilities.

1. Key personnel diagram, see Fig. II-15
2. Equipment and supplies inventory, see Fig. II-16
3. Mutual aid agreement and fact sheet, see Figs. II-17 and II-18.

Mutual aid agreements can be made between geographically adjacent agencies and businesses such as cities, fire departments, water companies, health departments, construction companies, industrial firms for the purpose of helping each other during CR.

4. As-built drawings of treatment plant.



Note: Names and phone numbers should be tabulated.

Fig. II-15. Sample Key Personnel Diagram for CR.

WASTEWATER TREATMENT SYSTEM
EMERGENCY INVENTORY

SYSTEM: ____

PREPARED BY: ______________________________ DATE: ______________
(Signature)

DUPLICATE EQUIPMENT IN STOCK

DESCRIPTION	MAKE	SIZE	TYPE	VOLTAGE	HP	CAPACITY	NO.

PARTS & COMPONENTS IN STOCK

DESCRIPTION	SIZE	NO.	APPLICATION IN SYSTEM

Fig. II-16. Sample Inventory Worksheet.

EMERGENCY EQUIPMENT & REPAIR TOOLS

DESCRIPTION	NO.	APPLICATION IN SYSTEM

PIPE	SIZE					
	TYPE					
	LENGTH					

AVERAGE	TYPE				
CHEMICAL	FORM				
STOCK	QUANTITY				

COMMUNICATIONS EQUIPMENT

DESCRIPTION	LOCATION

MAPS AND FACILITY LAYOUT DETAILS

OFFICIAL AUTHORIZING
INVENTORY

Fig. II-16. Sample Inventory Worksheet (continued).

MUTUAL-AID AGREEMENT *

EMERGENCY SITUATIONS COULD ARISE IN A MUNICIPALITY'S WASTEWATER TREATMENT SYSTEM THAT WOULD REQUIRE ASSISTANCE FROM AN ADJOINING MUNICIPALITY TO RESTORE NORMAL OPERATION.

IF AN EMERGENCY SITUATION ARISES IN ______________________ OR
(City)
______________ THE OFFICIALS IN BOTH MUNICIPALITIES AGREE
(City)
TO SUPPORT EACH OTHER DURING THE EMERGENCY.

EACH CITY HAS A CONTINGENCY PLAN FOR RESPONSE TO EMERGENCIES AFFECTING

ITS WASTEWATER TREATMENT SYSTEM. THE ______________ AGREES TO
(City)
SUPPORT ______________ IN THE FOLLOWING AREAS: ______________
(City) (Firefighting,

Rescue Crews, Communications, Portable Chlorination, Operational/

Maintenance, Personnel, etc.)

____ TO

THE EXTENT POSSIBLE UPON REQUEST INITIATED BY:

Name	Name
Title	Title
City	City

PERSONNEL RESPONDING TO THE REQUESTS FOR ASSISTANCE UNDER THIS AGREEMENT WILL REMAIN UNDER THE CONTROL OF THE CITY PROVIDING THEM.

Signed	Signed
Name	Name
Title	Title
City	City

*Similar to format suggested by Planning Section, Virginia Office of Civil Defense.

Fig. II-17. Sample Mutual Aid Agreement Form

SAMPLE MUTUAL AID INFORMATION FACT SHEET

NAME	DESCRIPTION OF ASSISTANCE	COORDINATION INFORMATION
Public Works Department	Department of Parks maintains 1,000 feet of 6 inch quick coupling aluminum pipe that is available to assist treatment system during emergencies.	To obtain pipe, contact Dept. of Parks (Phone) during normal working hours or call city switchboard (Phone) after normal working hours.
City Water Department	Water Department maintains 2 portable chlorinators which can be used for emergencies within the wastewater treatment system.	Contact Water Department Supt. (Phone) or operator on duty at main filter plant (Phone).
ABC Construction Company	4 tractor mounted back-hoes are available on a 24-hour basis.	Contact company main office (Phone) or after hours call John Doe, Equipment Foreman (Phone).
ACME Welding Company	Machine shop facilities and a portable welding machine are available on a 24-hour basis.	Call: (Phone) Office (Phone) Home (Phone) Home

Fig. II-18. Sample Mutual Aid Information Fact Sheet.

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	μm.		3.937 X 10^{-3}=10^3A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or megagram	t Mg	1 tonne = 1 000 kg 1 Mg = 1 000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N·m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2 230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2 120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa·s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	deqree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N·m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw·hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/t		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	lumen/m^2		0.092 ft candle/sq ft

7728-4 November 1978

EMERGENCY SEWAGE PROCEDURES
DURING
CRISIS RELOCATION

Part III-Non-Sewered Waste Disposal

prepared for

Defense Civil Preparedness Agency
Washington, D.C.

Contract No. DCPA01-77-C-0230
Work Unit 2422E

Dr. William Wisecup, COTR

by

R. Fisher
L. Dickinson, J. Meyer
Dr. T.P. Wagner

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Section 1

INTRODUCTION

Current Crisis Relocation (CR) plans require that a large proportion of the host area population be located in rural areas which are generally not served by public sewage systems. For example, Ref. 30 indicates that in rural areas sewers serve only 19% of the households, with septic tanks and cesspools serving 66% and the remaining 15% utilizing privies or discharging their sewage directly into drainage ditches or nearby streams.

It should also be noted that even in areas served by public sewers there are likely to be many non-sewered waste disposal problems. Consider, for example, the case where a warehouse is being used as a congregation care facility housing two or three hundred people but which contains only one or two bathrooms. To accommodate most of these people will most likely require supplemental non-sewered emergency facilities.

Unfortunatley the use of non-sewered facilities greatly increases the possiblity of waterborne and vectorborne transmission of diseases. See, for example, the data in Fig. III-1, which indicates the incidence of enteric disease for sewered and non-sewered situations. Other data from Refs. 1 and 2 indicate that 70% of the approximate 1,600 illnesses caused by outbreaks of waterborne disease each year occur in areas without municipal services. In summary, maintenance of public health will be a major concern during CR and proper sanitation and sewage disposal must be maintained to minimize the occurrence of disease. Historically maintenance of proper sanitation has been more difficult in non-sewered areas and under the pressures of the large increase in population during CR can be a major problem.

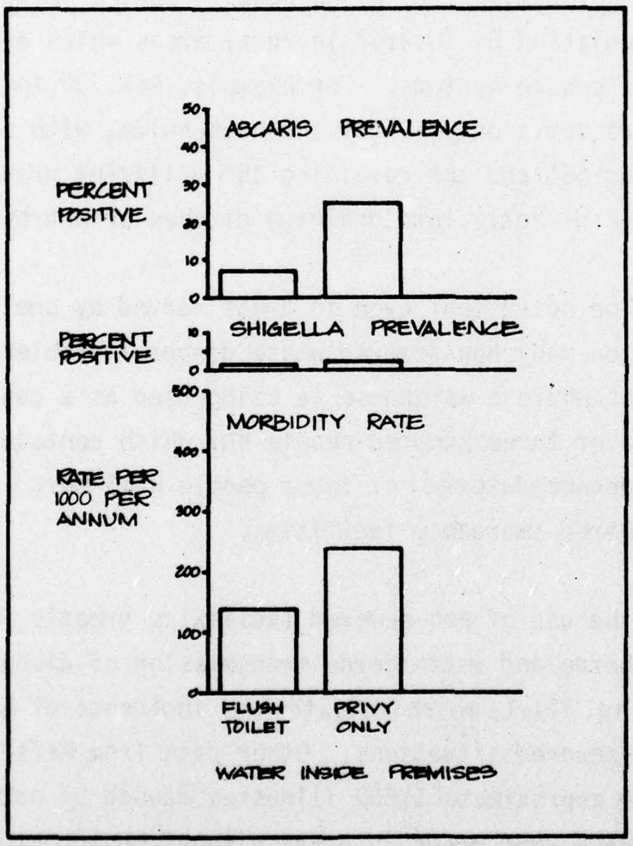


Fig. III-1. Diarrheal disease morbidity rates: Shigella infections in preschool children and percentage of study population infected with Ascaris, according to selected sanitary facilities, eastern Kentucky, 1954-56. Source: Ref. 31.

In most cases non-sewered disposal of wastes will utilize some type of "engineered" system, but without proper planning and control much of the disposal will be "opportunistic". An engineered system is defined as waste disposal using a facility to minimize nuisance and disease potential while opportunistic disposal is defined as the indiscriminate deposition of waste as the result of the inconvenience associated with the movement of people to the host area and the inconvenience associated with the increased population density overtaxing existing engineered systems. This latter condition, sometimes termed "promiscuous pissing" is to be avoided at all costs. Numerous instances of hepatitis and other infectious disease outbreaks following large uncontrolled gatherings of people, such as rock concerts, are cited in the literature. Numerous other cases are noted where small quantities of sewage entering a water system have spread disease through large numbers of people.

Thus it is imperative that the CR planners consider the problems of the non-sewered areas and that sufficient control be established to prevent "opportunistic" disposal. This problem will exist both during CR transit and after arrival at the host areas. It will probably be greatest during the early phases of the relocation while the relocatees are finding their permanent shelter. During this transition the number of proper toilets may be insufficient and the relocatees will probably not be aware of their location and availability. Proper management of the problem of opportunistic waste disposal should involve two methods: an extensive informational campaign and the enforcement of proper waste disposal. The informational campaign should stress the hazards of improper waste disposal and should include guidelines for safe disposal. A prototype safe disposal booklet is presented in Appendix A. The remainder of this part of the report is devoted to the so-called engineered sewage disposal systems; i.e., a waste disposal system designed to minimize the spread of disease.

Section 2 discusses existing facilities likely to be found in non-sewered areas. These include cesspools, septic tanks and privies. Section 3 discusses facilities which can be constructed during the crisis period to

supplement the existing facilities. Appendixes A, B, C, and D are sample pamphlets which could be distributed during the crisis period and are as follows: A - Methods of Safe Emergency Sewage Disposal, B - Household/ Congregate Care Center Water Reduction Ideas, C - Health Considerations Using Household Grey Water, and D - Septic Tank Maintenance.

Section 2
EXISTING FACILITIES

Cesspools and Septic Tanks

As of 1970 the EPA estimated that about 85% of onsite or non-sewered disposal systems were septic tanks or cesspools so that the majority of the existing engineered systems during CR will be either of these two types. A cesspool is a large, buried chamber, which is walled with a porous material such as concrete blocks. Cesspools serve the dual functions of a septic tank and percolation system receiving raw sewage directly from home plumbing fixtures. Cesspools are now generally prohibited by most local building codes.

A septic tank system on the other hand, consists of three basic components. The first is the septic tank itself, which is a watertight non-corrosive, and covered receptacle designed to remove solids by settlement and to trap and store scum and sludge. The second is the distribution box, which is needed to ensure equal distribution of effluent to the several lateral lines of the tile field. The third component is the soil absorption system or tile field. This consists of a series of pipes which are designed to distribute as evenly as possible the sewage effluent over an area of soil large enough to absorb it.

Septic tanks and cesspools both use underground disposal to isolate wastes from the environment, however, two mechanisms for contamination exist. One is contamination of the ground water by the transport of pathogenic organisms through soil into the water table and the other is contamination of the ground surface by transport of pathogenic organisms to the surface. Ground water contamination is usually caused by improper location of the tank and surface contamination is usually caused by ponding of wastes at the surface

when the hydraulic load exceeds the percolation capacity of the soil.

Although high degrees of purification of wastes can be achieved by relatively small depths of soil, cases of ground water contamination resulting in disease are known particularly with the following types of soil conditions (Ref. 30, pp 66-67):

1) Shallow soils over creviced bedrock,
2) Shallow soils over high ground water tables,
3) Impermeable soils.

Thus contamination of ground waters is usually caused not by the magnitude of the population served but by the physical configuration of the system. Therefore, in most cases, contamination of ground waters will exist prior to CR.

One effect of increased hydraulic flow during CR on drain field capacity is that continuous inundation of the soil will, even with clear water, eventually clog the soil. When this occurs sewage will migrate to the surface leading to vectorborne or surface waterborne contamination. Thus, the longer any CR continues, the greater the chance for septic tank failure.

Septic tank problems can be identified by a back-up of drains within the house or by standing moisture or wet earth over the underground disposal. If this occurs the hydraulic waste flow must be reduced. Some potential methods of flow reduction are water conservation and the separation of "grey water". Various water conservation ideas are presented in a sample pamphlet included as Appendix B. Fig. III-2 illustrates different grey water disposal systems. Appendix C includes sample pamphlets on alternative grey water disposal systems and suggestions on the use of grey water.

Another problem likely to be encountered is overloading. Proper operation of a septic tank requires periodic removal of the accumulated solids by pumping the tank contents. If excessive solids are allowed to accumulate in the septic tank, some of the solids can be carried over into the drain field causing plugging. Thus, the increase in solids load as a result of CR can be handled adequately by increasing the frequency of septic tank pumping. A

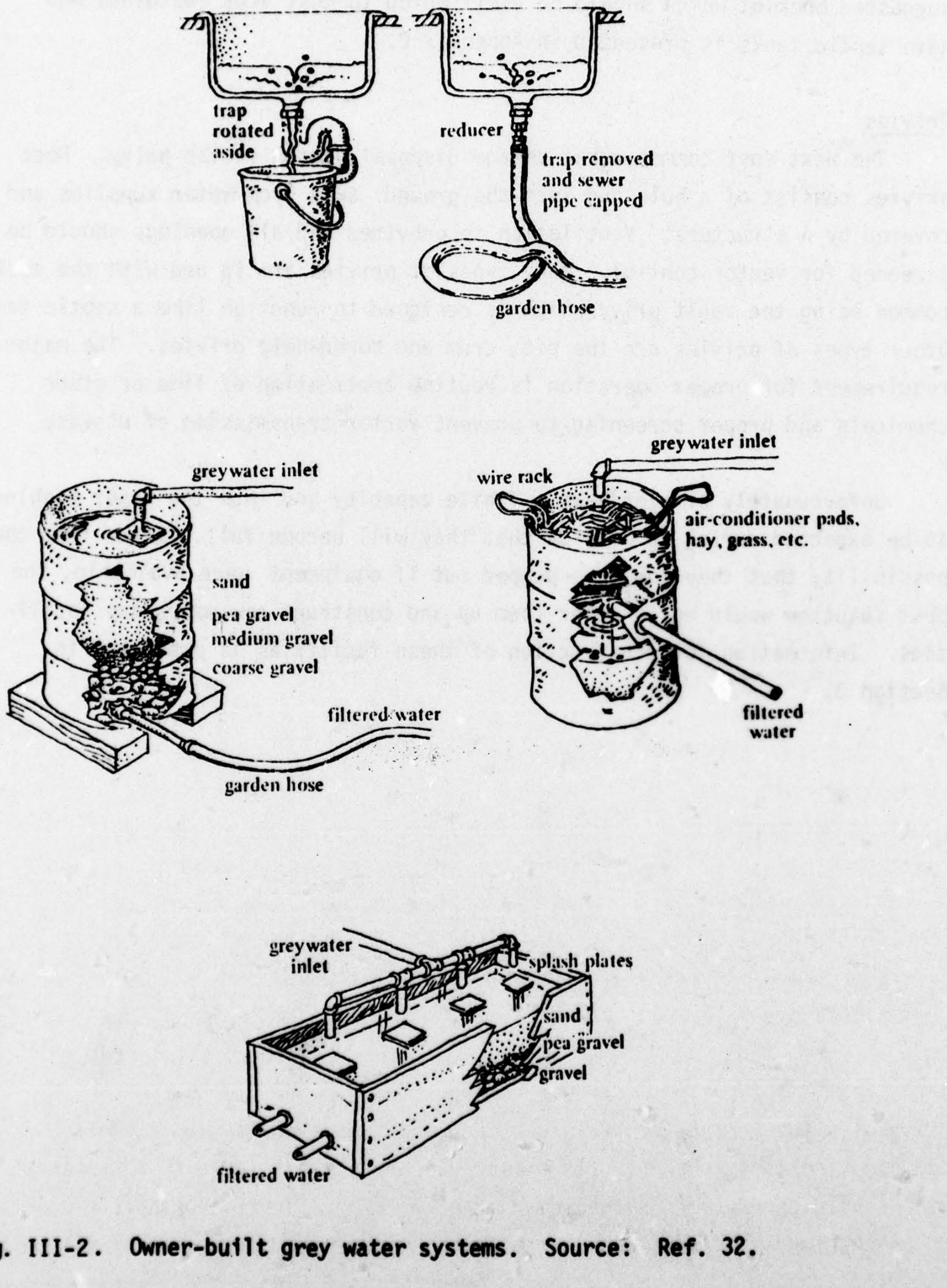


Fig. III-2. Owner-built grey water systems. Source: Ref. 32.

suggested booklet which should be distributed to host area residents who have septic tanks is presented in Appendix D.

Privies

The next most common rural sewage disposal system is the privy. Most privies consist of a hole dug into the ground away from water supplies and covered by a structure. Ventilation is provided and all openings should be screened for vector control. Many types of privies are in use with the most common being the vault privy which is designed to function like a septic tank. Other types of privies are the pit, drum and bored-hole privies. The major requirement for proper operation is routine application of lime or other chemicals and proper screening to prevent vector transmission of disease.

Unfortunately privies have a finite capacity and thus the major problem to be expected during CR will be that they will become full. Aside from the possibility that they could be pumped out if equipment were available, the best solution would be to cover them up and construct new emergency facilities. Information for construction of these facilities is presented in Section 3.

Section 3

EMERGENCY FACILITIES

INTRODUCTION

In addition to the existing facilities discussed in Section 2 numerous emergency facility alternatives exist including pit privies and latrines, new septic tanks and sanitation systems such as a combined aqua privy and oxidation pond.

The primary concern with any of these facilities is location and local health officials should be consulted wherever possible. General rules are as follows:

- o Avoid contamination of water supply — do not locate emergency sewage facility near or at a location where contaminants can enter a water system. Avoid shallow soils over creviced hard rock, shallow soils over high ground water tables and impermeable soils.
- o Keep them clean and protected from insects, rodents, and other disease transmitting vectors.
- o Obtain an adequate supply of chemicals and equipment for adequate maintenance.
- o Initiate a stringent maintenance and control procedure.

EMERGENCY FACILITIES

Following are brief descriptions of candidate emergency facilities.

Privies

As noted in the existing facilities section, a privy is essentially a hole dug in the ground and covered by a structure suitable to keep out

vectors and the weather. They can be installed quickly and easily if the necessary equipment and materials are available. For guidance on location and installation of privies refer to the latrine discussion later in this section.

Chemical Toilets

There are a wide variety of chemical and portable toilets which are used at construction sites, in recreational vehicles, etc. Use of these facilities during CR depends on their availability, and the availability of chemicals and support equipment to keep them maintained. Previous experience with these facilities at natural disasters and large gatherings of people indicate that stringent control and continuous maintenance is a necessity.

Military Latrines

The U.S. Department of the Army has published extensive manuals on field sanitation methods. These manuals give detailed step-by-step instructions on the construction or use of many methods which could be temporarily used during CR as emergency waste disposal facilities. The following discussion on the construction of latrines is included verbatim from the U.S Army FM 21-10, (Ref. 33).

78. Construction of Latrines

The following general rules apply to the construction of all types of latrines:

a. To make sure that food and water will be protected from contamination, latrines should be built at least 100 yards from the unit mess and the nearest water source. Also, the latrine should not be dug below the water level in the ground nor in a place where it may drain into a water source. Usually, latrines are built at least 30 yards from the end of the unit area but within a reasonable distance for easy access. At night, if the military situation permits, they should be lighted. If lights cannot be used, a piece of cord or tape may be fastened to trees or stakes to serve as a guide to the latrine.

b. A canvas or brush screen should be placed around each latrine, or the latrine may be enclosed within a tent. In cold climates this shelter should be heated. The screen or the tent should have a drainage ditch dug around its edges to prevent

water from flowing over the ground into the latrine. For fly control, these shelters should be sprayed twice weekly with an approved insecticide.

c. On the outside of each latrine enclosure a simple hand-washing device should be installed. This device should always be kept filled with water and should be easy to operate.

d. Latrines should be policed every day. Certain unit personnel should be assigned the responsibility of ensuring that the latrines are being properly maintained.

e. When a latrine has been filled to within one foot of the surface, or when it is to be abandoned, it should be closed in the following manner: the contents of the pit, the side walls, and the ground surface to a distance of two feet from the side walls should be sprayed with an insecticide. Then the pit should be filled to the ground surface with successive 3-inch layers of earth. Each layer is packed down and its surface is sprayed with insecticide before the next layer is added. Then the latrine pit is mounded over with at least one foot of dirt. The purpose of this method of closing is to prevent any immature fly that may hatch in the closed latrine from getting out. The location of the latrine should then be plainly indicated with a sign which is marked CLOSED LATRINE and is dated.

79. <u>Straddle Trench Latirnes</u>

A straddle trench latrine is dug 1 foot wide, 2½ feet deep, and 4 feet long. This will accommodate two men at the same time. The number of trenches provided should be sufficient to serve at least 8 percent of the unit strength at one time. Thus, for a unit of 100 men, at least 16 feet of trench, or 4 straddle trench latrines are needed (Fig. III-3). The trenches should be at least two feet apart. There are no seats in this type of latrine, but boards may be placed along both sides of the trench to provide better footing. Toilet paper should be placed on suitable holders and protected from bad weather by a tin can or other covering. The earth removed in digging is piled at the end of the trenches and a shovel or paddle is provided. This is done so that each man can promptly cover his excreta and toilet paper. When the unit leaves the area, or when the straddle trenches are filled to within one foot of the surface, the trenches should be closed in the manner described in paragraph 78e.

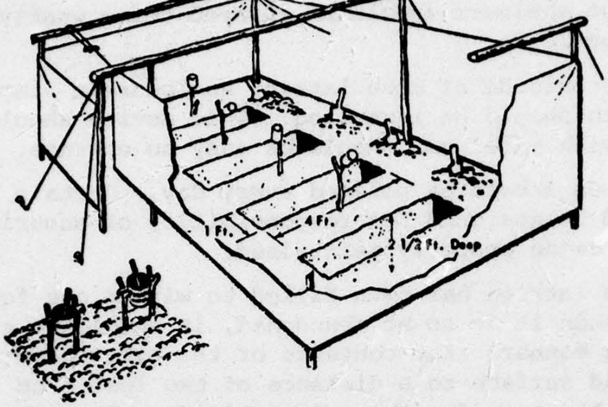


Fig. III-3 ***Straddle trench latrines for 100 men, with handwashing device.***

80. Deep Pit Latrines

The deep pit latrine is used with a latrine box. The standard type box provides four seats and is 8 feet long and 2½ feet wide at the base. A unit of 100 men requires 16 feet of latrine space, or two latrine boxes (Fig. III-4). The holes should be covered with flyproof, self-closing lids. All cracks should be flyproofed with strips of wood or tin nailed over them. A metal deflector should be placed inside the front of the box to prevent urine from soaking into the wood.

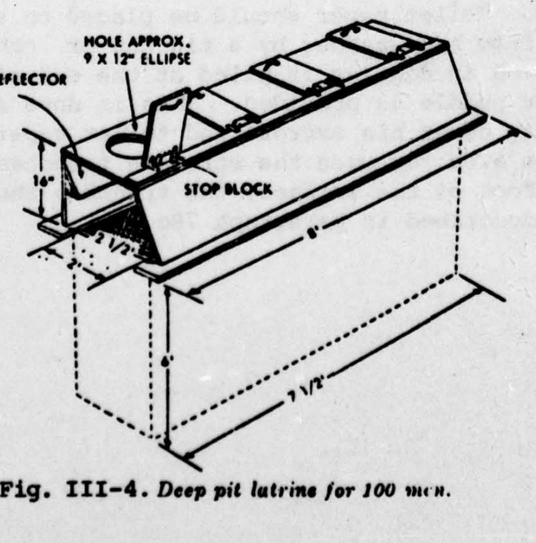


Fig. III-4. ***Deep pit latrine for 100 men.***

a. The pit is dug 2 feet wide and 7½ feet long. This will give the latrine box 3 inches of support on all sides. The depth of the pit will depend on the estimated length of time the latrine is to be used. As a rough guide, a depth of one foot is allowed for each week of estimated use, plus one foot of depth for the dirt cover. Generally, it is not desirable to dig the pit more than six feet deep because of danger that the walls may cave in. Rock or high ground water levels often limit the depth of the pit. In some types of soil a support of planking or other material for the sides may be necessary to prevent cave-ins. Earth should be packed tightly around the bottom edges of the box so as to seal any openings through which flies might gain entrance.

b. In order to prevent flybreeding in the pit and to reduce odors, it is necessary to keep the latrine box clean, the seat lids closed, and the cracks sealed; also, a good fly control program must be maintained in the area. The use of lime in the pit, or the burning out of the pit contents, is not effective for fly or odor control and is not recommended. For fly control, the interior of the box and the contents of the pit should be sprayed twice weekly with a residual fly spray. The box and the seats of the latrine should be scrubbed daily with soap and water. When a unit leaves the area, or when deep pit latrines are filled to within one foot of the ground surface, the latrines should be closed in the manner described in paragraph 78e.

81. Mound Latrine

This type of latrine may be used when a high ground water level, or a rock formation near the ground surface, prevents the digging of a deep pit. A dirt mound makes it possible to build a deep pit latrine and still not have the pit extending into the water or the rock (Fig. III-5).

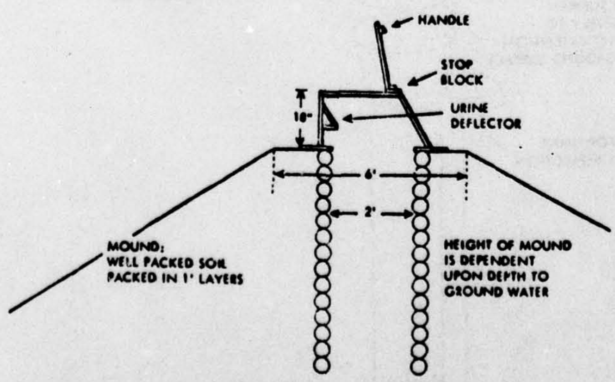


Fig. III-5. *Mound latrine.*

a. A mound of earth having a top at least 6 feet wide and 12 feet long should be constructed so that a 4-hole latrine box may be placed on its top. The mound should be high enough to meet the pit's requirement for depth, allowing one foot from the base of the pit to the water or the rock level. Before the mound is built, the area where it is to be placed should be broken up or plowed in order to aid seepage of liquids from the pit. The mound is then built in 1-foot layers. The surface of each layer is roughened before the next is added. When the desired height has been reached, the pit is dug into the mound. It may be necessary to brace the walls with wood, sandbags, or other suitable material to prevent cave-ins. The size of the base of the mound will depend on the type of soil in the area and should be made larger if the slope is too steep. It may be necessary to build steps up the slope.

b. The mound latrine should be flyproofed in the same manner as is the deep pit latrine. It also is closed in the same manner as is the deep pit latrine.

82. <u>Bored-Hole Latrine</u>

This type of latrine consists of a hole, about 18 inches in diameter and from 6 to 20 feet deep, covered by a one-hole latrine box (Fig. III-6). A converted metal drum may be sunk into the ground for use as a box. Both ends of the drum are removed and a flyproof seat cover, with a self-closing lid, is made to fit the top of the drum. This type of latrine is satisfactory for small units, provided the necessary mechanical equipment for boring the hole is available.

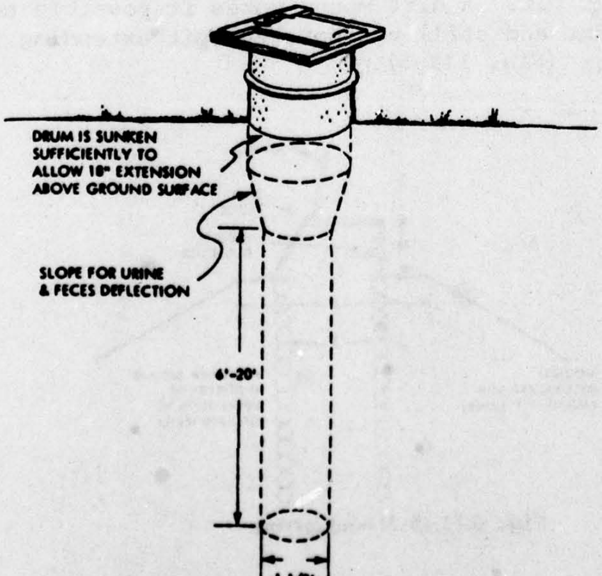


Fig. III-6. *Bored-hole latrine.*

83. Pail Latrine

A pail latrine may be built when conditions (populated areas, rocky soil, marshes) are such that a dug latrine cannot be used.

a. A standard type latrine box may be converted for use as a pail latrine by placing hinged doors on the rear of the box, adding a floor, and placing a pail under each seat. If the box is located in a building it should be placed against the outer wall so that the rear of the box opens directly to the outside of the building (Fig. III-7). The seats and rear door should be selfclosing and the entire box made flyproof. The floor of the box should be made of an impervious material (concrete, if possible) and should slope enough toward the rear to facilitate rapid draining of washing water. A urinal may also be installed in the latrine enclosure with a drainpipe leading to a pail outside. This pail also should be enclosed in a flyproof box.

b. Pails should be cleaned at least once daily: oftener if necessary. The contents may be buried, burned, or disposed of by other sanitary methods. After having been cleaned, when the pails are replaced they should contain one inch of Quartermaster disinfectant.

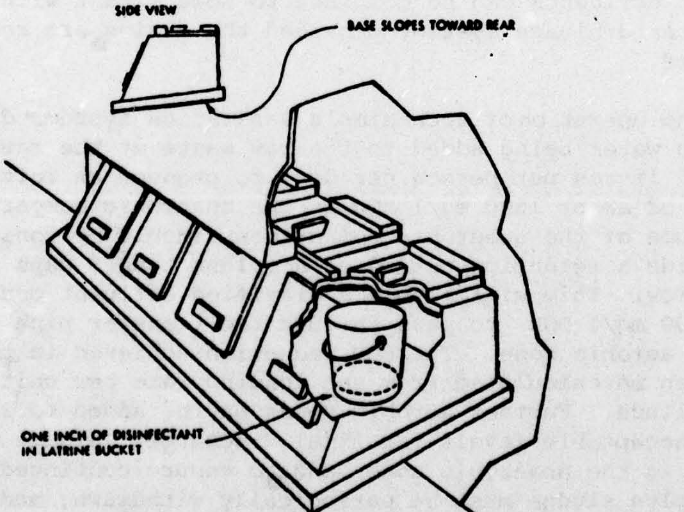


Fig. III-7. *Pail latrine in building.*

Combination Aqua Privy and Oxidation Pond

Fig. III-8 shows the plans and specifications for an emergency sanitation system for 200 people which is a combination aqua privy and oxidation pond. The following description is taken verbatim from Mann, (Ref. 34):

"For large-scale emergency facilities black polythene film has many uses, as well as being light, cheap, and easy to transport by air. A form of aqua privy combined with an oxidation pond may be constructed by digging a lagoon and lining it with polythene film reinforced with polythene bags filled with soil after the fashion of sandbags. A polythene sheet 20 ft by 100 ft can provide an emergency sewage treatment plant for about 200 people or more.

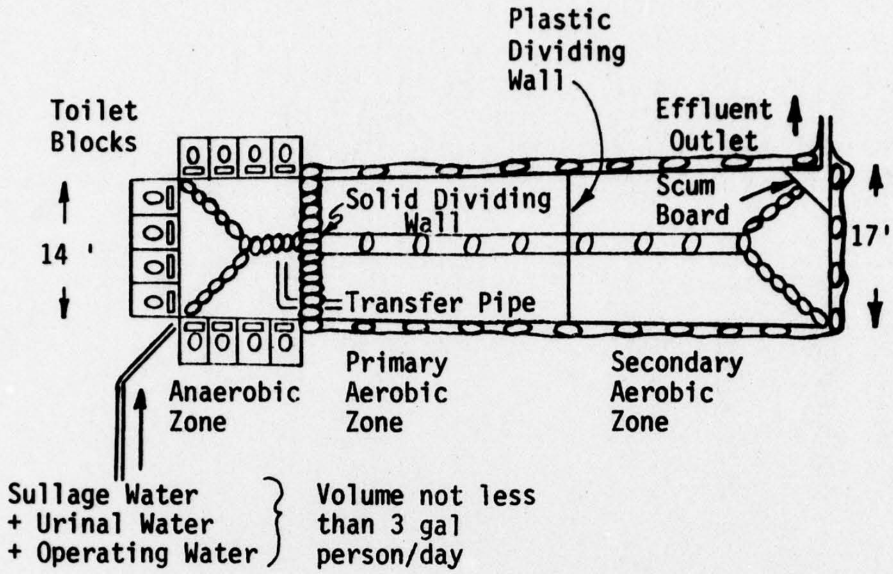
"The selection of a suitable site can make the organization of public health matters easier. A sloping site with good surface drainage which can be improved by trenching should be selected, not too close to the water source, so that surface drainage can be diverted to the downstream side of the water abstraction site. Treatment plants must be partially filled with water before use, (surface water will suffice) and after the plants are functioning, the effluents can be combined to some extent with the surface water drainage system, provided the drains are reasonably protected.

"The operation of such simple sanitation systems depends on diluting water being added to the raw waste at the rate of about 20 to 25 litres per person per day, to produce an initial concentration of about 1500 mg/l BOD in the anaerobic compartment. The volume of the anaerobic compartment should be constructed to provide a retention period of not less than 2 days to the total flow. This will enable a clarified effluent containing about 500 mg/l BOD to pass through the transfer pipe to the primary aerobic zone. The BOD reduction achieved in the aerobic zones can be calculated from the loading rate per unit area, and the latitude. Further aerobic ponds may be added to reduce the BOD to acceptable levels for final discharge. Sludge accumulates rapidly in the anaerobic zone, and to ensure continued functioning surplus sludge must be periodically withdrawn, and stored in plastic storage containers fitted with gas vents. After a period of 3 to 6 months the sludge will be well digested and almost free from harmful organisms, and then may be buried or discharged on land."

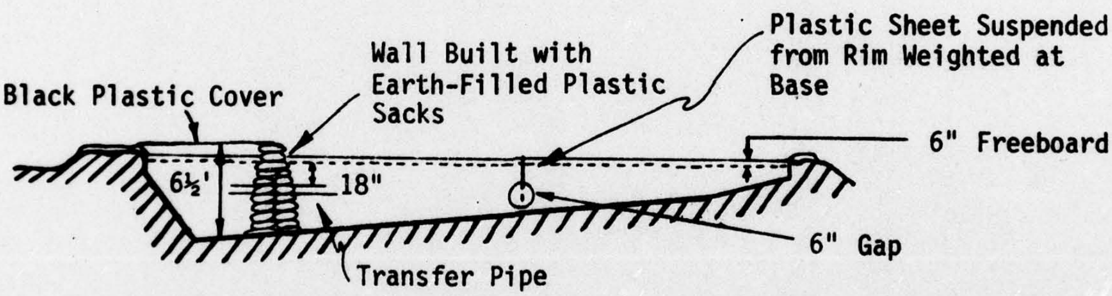
1 Sheet of Black Plastic Film 20 ft. x 100 ft.

12 Squatting Plates with Drop Pipes

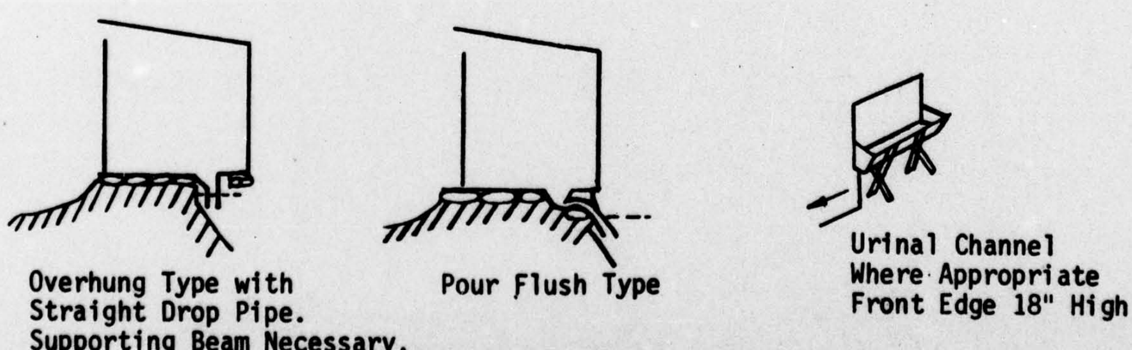
Polythene Sacks, Pipe, Spare Sheet, Rope and Rough Timber



PLAN



SECTION



Toilet Arrangements

Notes: 1. Effluent quality depends on pollution load, adequate hydraulic flow and adequate sunshine.
2. Fill with water before use. Desludge anaerobic zone as necessary.
3. Perimeter of excavation must be fenced for safety purposes.

Fig. III-8. Combination Aqua Privy and Oxidation Pond for 200 People.

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APPENDIX A

METHODS OF SAFE EMERGENCY SEWAGE DISPOSAL[4]

WATER FLUSH TOILETS cannot be used, of course, when water service is interrupted. The water remaining in the fixture is not sufficient to flush the wastes down the sewer. Clogging may result, and your living conditions then become just that much more uncomfortable.

Even if water is available, local authorities may ask you not to use flush toilets, wash basins, and other fixtures connected with soil pipes. The sewer mains may be broken or clogged, which would make it impossible to carry off such wastes. Or water may be needed for fire fighting. It is necessary for every family to know emergency methods of waste disposal, in case such conditions arise.

Failure to dispose of human wastes properly can lead to epidemics of such diseases as typhoid, dysentery, and diarrhea. Sewage must be disposed of in ways that will prevent contamination of water supplies used for drinking, cooking, bathing, laundering, and other domestic purposes. Here are simple steps that a family can take to prevent such dangers and discomforts:

a. Right after a disaster, or during, you will probably not have the time and tools to prepare a complex emergency sanitation system. If there is a delay of several days in restoring sewerage service to your neighborhood, you may find that disposal is a big problem. Your first task, however, is to make some temporary toilet provision for members of your family, especially the children. Almost any covered metal container will do. You can use a covered pail. A small kitchen garbage container with a foot-operated cover can be put to toilet use in emergencies. Anything that has a cover and will hold the contents until you can dispose of them will serve for sanitary purposes, at first.

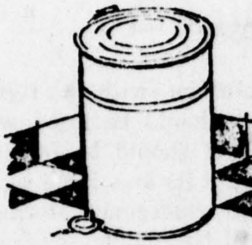
b. Keep on the premises at least one extra 10-gallon garbage can or other waterproof container with a tightly fitted cover. This should be lined with paper, and the cover should be fastened to the can to prevent its loss. Such a can may be used for the emergency storage of body wastes until the public sewerage system can be put back into action, or until other arrangements can be made. Empty your smaller vessel into it as often as necessary. A small amount of household disinfectant should be added after each use. If you live in an apartment, you may not have a large garbage can or room to keep one. In that case two smaller covered pails or other containers will do just as well.

c. Keep a shovel on the premises if there are unpaved yard areas nearby. Burying human waste matter under 12 to 24 inches of earth is a satisfactory method of emergency disposal. Never deposit wastes, liquid or solid, on the surface of the ground. Insects and rodents may carry infections to other humans.

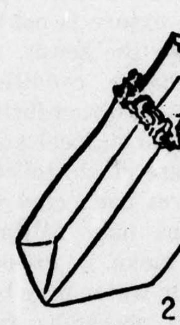
d. Where radioactive fallout does not present a hazard, a temporary pit privy may be constructed in a yard area for use by several families. This offers a good method of waste disposal over extended periods of time. The structure need not be elaborate, so long as it provides reasonable privacy and shelter. The pit should be made flyproof by means of a tight-fitting riser, seat, and cover. A low mound of earth should be tamped around the base of the privy to divert surface drainage and help keep the pit dry. Accumulated waste should be covered with not less than 12 inches of earth when the privy is moved or abandoned. Outdoor toilets should not be located in areas that are subject to flooding, and should be built at least 50 feet from any well, spring, or other source of water supply. Otherwise the wastes may contaminate

[4] This appendix may be adapted to local requirements by the sewerage utility, in cooperation with the community civil defense organization, for distribution to householders.

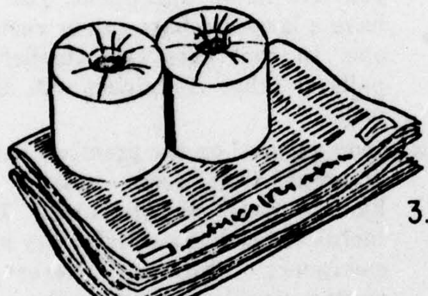
FOR PROPER SEWAGE DISPOSAL YOU WILL NEED....



1. Covered container for bathroom.

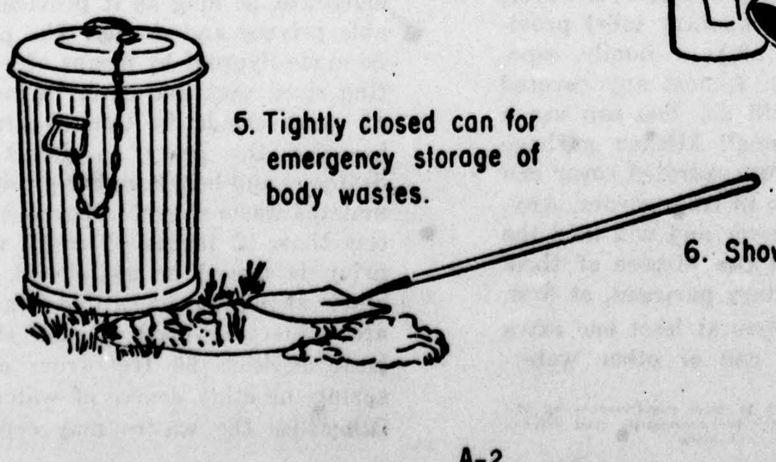


2. The materials to make soil bags.



3. Newspapers, extra toilet tissue.

4. Insecticide and deodorants.



5. Tightly closed can for emergency storage of body wastes.

6. Shovel

the water. Or, they might be washed out of the pit and deposited on the ground surface where they would be exposed to flies, rodents, and other animals that might serve as disease carriers.

e. Persons in city apartments, office buildings, or homes without yards should keep a supply of waterproof paper containers on hand for emergency waste disposal. Where flush toilets cannot be used and open ground is not available for the construction of privies, such disposable containers offer a practical method of emergency waste collection and disposal. Building managers should plan for the collection of such containers and for their final disposal. Before collection, the used containers may be stored in tightly covered garbage cans or other waterproof utensils fitted with lids. Homemade soil bags for this purpose may be prepared very easily by putting one large grocery bag inside another, with a layer of shredded newspaper or other absorbent material between. Apartment dwellers should have sufficient grocery bags on hand now for possible emergencies. A supply of old newspapers will come in handy for other sanitary uses, too, such as wrapping garbage and lining larger containers.

f. Insecticides and deodorants should be used when necessary to control odors and insect breeding in containers that cannot be emptied immediately. At least 2 pints of household bleach solution should be kept on hand for disinfecting purposes.

g. Keep on hand an extra supply of toilet tissue, plus a supply of sanitary napkins. If there is illness in the house that requires rubber sheeting or other special sanitary equipment, make sure that adequate supplies are available. At least a week's accumulation of daily newspapers will come in handy for insulating bedding from floors, and lining clothes against cold, as well as for the sanitary uses already mentioned.

h. If you have a baby in your home you may find diaper laundering a problem under disaster conditions. It is best to keep an ample supply of disposable diapers on hand for emergency use. If these are not available, emergency diaper needs can be met by lining rubber pants with cleansing tissue, toilet paper, scraps of cloth, or other absorbent materials. Or, any moisture-resistant material can be cut and folded to diaper size and lined with such absorbent material.

Source: "Civil Defense Management for Sewage Systems", An Industrial Civil Defense Handbook, Department of Defense, Office of Civil Defense, FG-F 3.42, November 1969.

APPENDIX B

Sample Pamphlet

HOUSEHOLD/CONGREGATE CARE CENTER WATER REDUCTION IDEAS

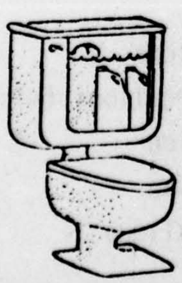
Household water conservation will be very important during CR, not only because potable water may be in short supply, but also because of its impact on the operation of sewage treatment facilities. A lot of water in the home may be going to the sewer needlessly, adding to the volume of sewage and putting an extra burden on treatment plants.

Here are some suggestions for reducing the amount of water flowing into the sewers.

<u>Bathing</u> Showers generally use less water than baths, especially when using a low-flow shower head. Turn off the shower while lathering; then rinse off. Bathe children together.

<u>Washing Hands</u> Do not run the faucet continuously; fill the wash basin.

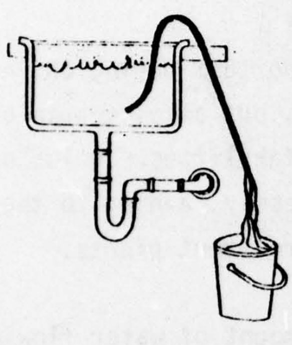
<u>Brushing Teeth</u> Fill a drinking glass and use it for rinsing rather than running the faucet while brushing.



<u>Toilets</u> Remember the toilet is not a trash can — use the waste basket. Do not flush the toilet needlessly ("If it's yellow-let it mellow, if it's brown-flush it down"). Place weighted plastic bottles or bricks in the tank to reduce the flow per flush.

<u>Kitchen</u> With automatic dishwashers only run when fully loaded. If hand washing is done, a sink full of wash water and one of rinse water will do. Don't let water run when washing produce; rather put a stopper in the sink. For drinking water, store a jug in the refrigerator.

Laundry Washing machines use 40 to 50 gallons of water per wash so be sure each load is full. The rinse water from the washer can be ponded in a wash basin and diverted for grey water use. Hand washed clothing should be done in a stoppered basin.



Grey Water Grey water is any wastewater not originally in the toilet. If collected during CR, grey water can be used for other purposes (e.g., flushing toilets or watering plants) thus not only saving water but also reducing the flow to the sewage treatment plant. The figure shows how grey water can be siphoned from any water basin. Alternatively, the "P" trap can be disconnected allowing direct collection of grey water (if this is done, the drain pipe should be capped to prevent overflowing in case of a plugged sewer line).

The following table cites some examples of the water use reduction that can be achieved in the home/congregate care center.

	Examples	Normal Use	Conservation
Kitchen			
	Dishwashing	30 gallons	5 gallons
	Automatic dish-washing	16 gallons	Use fully loaded
Bathroom			
	Shower	25 gallons	4 gallons
	Tub	36 gallons (full)	10-12 gallons (minimum)
	Handwashing	2 gallons	1 gallon
	Teeth brushing	10 gallons	½ gallon
	Toilet flush	5-7 gallons	4-6 gallons
Laundry			
	Washing machine	40-50 gallons	Use fully loaded

APPENDIX C

HEALTH CONSIDERATIONS USING HOUSEHOLD GREY WATER

"ALTERNATIVE GREYWATER DISPOSAL SYSTEMS"

By: William Jopling

REQUIREMENTS FOR GREYWATER SYSTEMS

(a) Site Requirements. Greywater disposal systems shall be installed only on sites that fulfill the following site requirements:

1. Greywater disposal system shall not be installed on sites where fissured rock is evident or on extreme slopes.

2. Groundwater levels shall be at least 5' below the bottom of the drainfield trench.

3. The soil at the disposal site shall have a percolation rate not slower than 60 minutes per inch. Percolation tests are recommended to determine the percolation rate and these tests shall be performed in accordance with the requirements of the local authority.

(b) Operational Requirements.

1. The greywater disposal system shall only be used for the disposal of domestic wastewater produce from kitchen, labatory, bath or laundry facilities. Toilet waste shall not be disposed of in a greywater system.

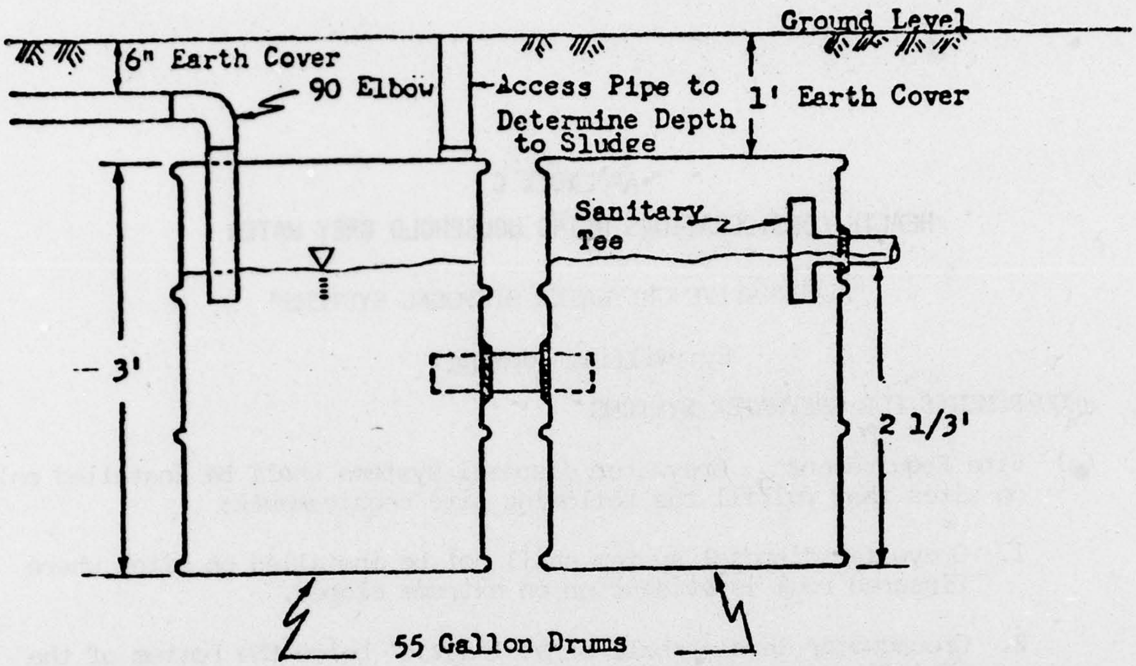
2. Accumulated solids should be removed every two years, or sooner, from the sedimentation tank and disposed of in a manner approved by the local health authority.

(c) Design Requirements.

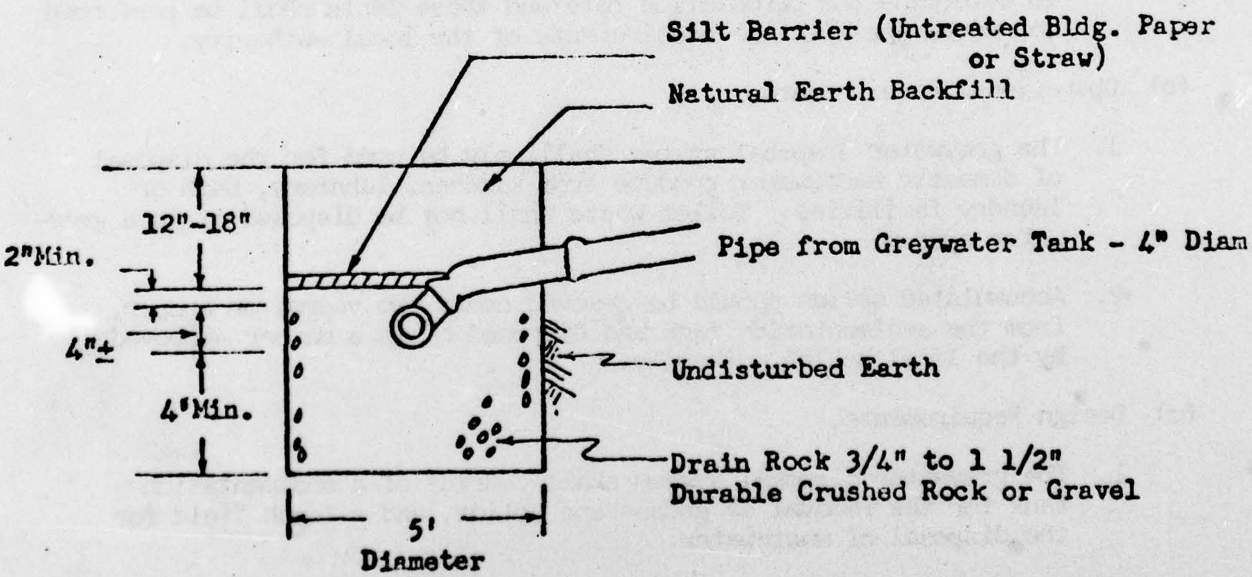
1. The greywater disposal system shall consist of a sedimentation tank for the removal of grease and solids, and a leach field for the disposal of wastewater.

2. The sedimentation tank would have a minimum capacity of 300 gallons and shall be constructed according to the accompanying diagram and specifications.

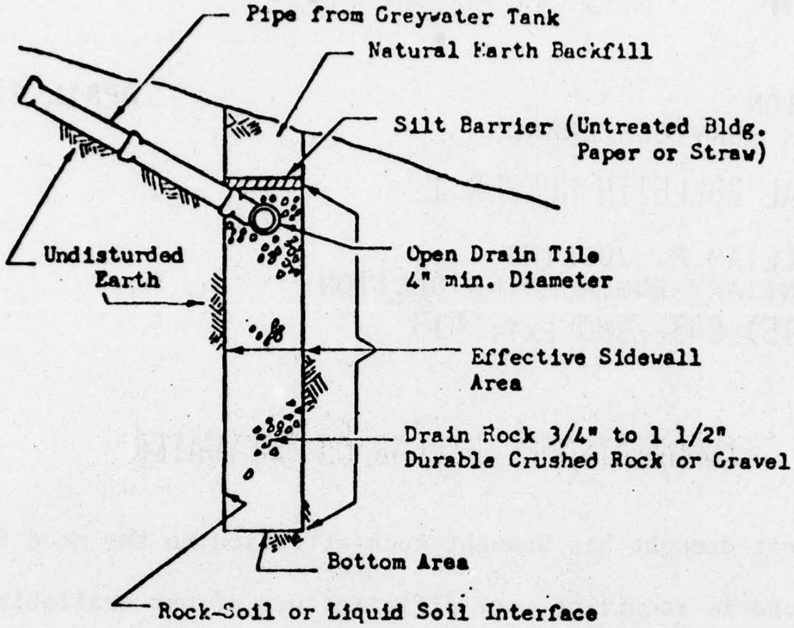
3. The sedimentation tank should be two compartments, the first compartment 2/3, the second compartment 1/3 of the total capacity.

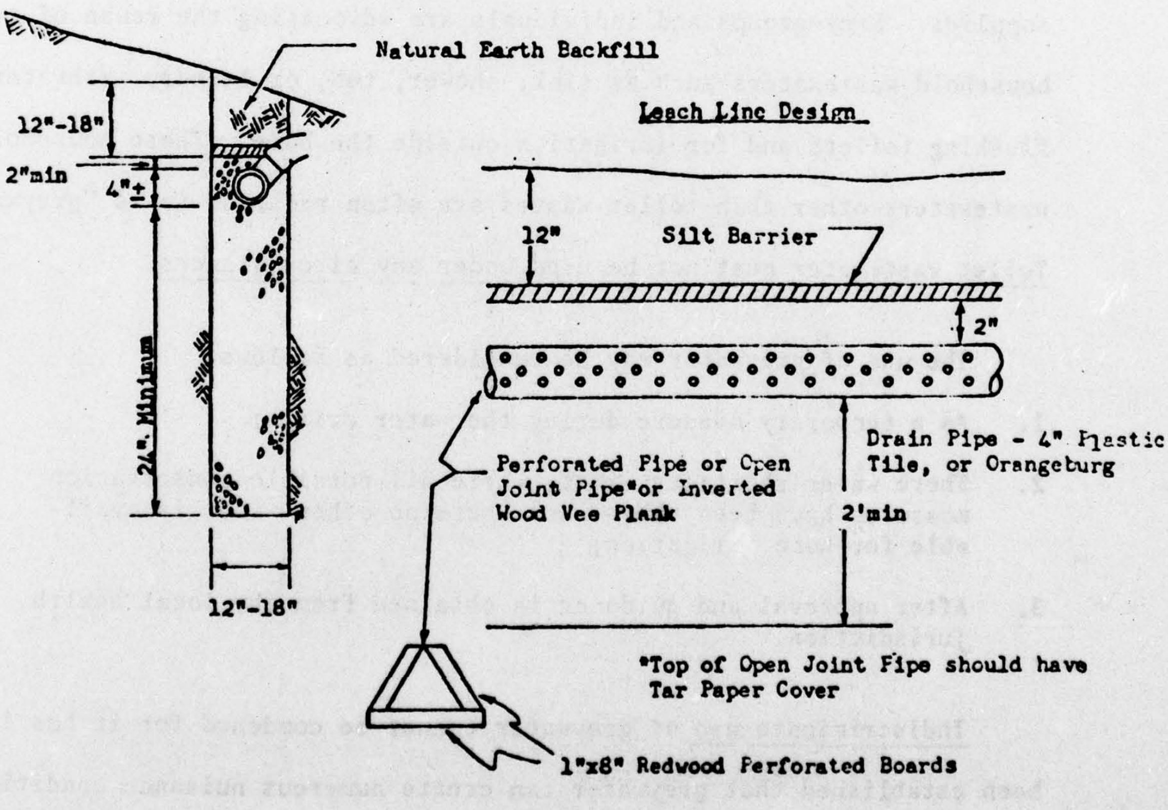


SEEPAGE PIT DESIGN



Leach Field Trench Design





Source: California State Water Resources Control Board; Rural Wastewater Disposal Alternatives, September 1977.

STATE OF CALIFORNIA—HEALTH AND WELFARE AGENCY Sample Pamphlet EDMUND G. BROWN JR., Governor

DEPARTMENT OF HEALTH
2151 BERKELEY WAY
BERKELEY 9470-

PUBLIC HEALTH DIVISION
ENVIRONMENTAL HEALTH SERVICES BRANCH

APRIL 27, 1977

DROUGHT INFORMATIONAL BULLETIN NUMBER 1

CONTACT PERSON: WILLIAM F. JOPLING
SANITARY ENGINEERING SECTION
(415) 843-7900 EXT. 413

INFORMATION CIRCULAR ON GREYWATER

The current drought has brought much attention to the need for water conservation and is requiring more efficient use of our available water supplies. Many groups and individuals are advocating the reuse of certain household wastewaters such as sink, shower, tub, or laundry washwaters for flushing toilets and for irrigation outside the home. These household wastewaters other than toilet wastes are often referred to as "greywater." Toilet wastewater must not be used under any circumstances.

The use of greywater may be considered as follows:

1. As a temporary measure during the water crisis;
2. Where water shortages exist, where all possible conservation measures have been taken, and where no other water is available for home irrigation;
3. After approval and guidance is obtained from the local health jurisdiction.

Indiscriminate use of greywater cannot be condoned for it has long been established that greywater can create numerous nuisance conditions and may be a potential source of waterborne disease.

Sample Pamphlet

Recommended Practices and Procedures

- The only recommended interior use of greywater is the dumping of bath water, dish water, or sink water directly into the toilet bowl for flushing. Greywater can be placed in the toilet tank only after physically disconnecting the water inlet pipe to the toilet. This must be done if greywater is to be placed in the toilet tank because a drop in pressure could draw the greywater back into the domestic water lines.

- Any modifications to plumbing systems should be done only after being approved by the local health and building authorities. The plumbing should be returned to normal after the emergency has passed.

- The storage of greywater must be accomplished in a manner that will minimize the problems of odors, vermin, insects, and safety. All storage containers should be screened or covered to exclude rodents and insects. Large containers may become attractive nuisances and pose a safety hazard to children.

- Grease and food scraps should be scraped off of dishes prior to washing in order to minimize insect and odor problems if this water is to be reused.

- Outside irrigation should be done in a manner that will minimize possible health risks and nuisances. Irrigation by greywater should not result in ponding or runoff of the water. This can be avoided by constructing berms around trees, shrubs, or plants and assuring rapid percolation by utilizing gravel or other porous material. Irrigation through perforated underground irrigation pipe is preferred.

- Greywater should not be used on root or low-growing food crops that will come in contact with the water.

- If a family member is ill from a diarrheal disease, do not use their shower, bathtub or laundry greywater for irrigation.

- Homeowners are urged to contact gardening or agricultural experts prior to irrigation with greywater. Many household chemicals may be toxic to, or otherwise adversely affect, vegetation.

ARE YOU USING GRAY WATER DURING THE DROUGHT?

Health Considerations Using Household Waste Water

RESOURCE EVALUATION OFFICE
DEPARTMENT OF WATER RESOURCES

The following information has been prepared* to supplement the Drought Information Bulletin Number 1. "Information Circular on Gray water", released April 27, 1977 by the Public Health Division of the Department of Health.

What is Gray Water?

Gray water is all waste water which comes from a home except for toilet waste water (or black water). Gray water includes the waste water from showers, bath tubs, bathroom sinks, kitchen sinks, clothes washing or washing machines, and dishwashing or automatic dishwashers. Gray water has been approved for use to flush toilets or irrigate landscape in some drought impacted areas for the duration of the drought when guidance and approval have been given by local health authorities.

What are the health concerns?

Approval of the reuse of water has been with the concern however, that the public be informed on the safest and most reasonable use of gray water. The public health officials warn that gray water has the potential of creating nuisance conditions when ponding or runoff of the water attracts flies and rodents or creates mosquito breeding sites or odors. The water can also contain bacteria and viruses and be the source of such water borne diseases as typhoid fever, dysentery and infectious hepatitis. It may also carry certain parasites. The insects and rodents which may be attracted to the waste water can be carriers of these disease producers. Gray water storage containers can be a hazard if children can acquire access to them.

When is the use of gray water allowed?

Gray water is defined by the Health and Safety Code as sewage and prohibits its discharge where a threat to public health or nuisance may be created. According to the Uniform Plumbing Code, waste water cannot be disposed by any means except an approved plumbing and sewage system. However, local authorities can adopt modifications of the code to meet the needs of local conditions such as water shortages. Changes in plumbing in order to collect gray water are not being recommended by most health departments, but approval emphasizes that changes should be temporary for the duration of the drought. Further consideration of health and design requirements for making future changes in codes is a next step to possible long-term water conserving household gray water systems. In the meantime, until such permanent systems are developed and approved, those of you who are in rationed, water short areas should be aware of the recommendations of health officials and plant specialists concerning gray water use.

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*The above information was prepared by the Resource Evaluation Office of the Department of Water Resources upon consulting representatives of local and State health officials. The U. C. Cooperative Extension Leaflet No. 2968. "Using Household Waste Water for Plants", a publication also available from the Department of Water Resources, was cooperatively produced by the Environmental Horticulture Department, University of California, Davis, the University of California Cooperative Extension at Davis and Riverside; the Resource Evaluation Office of the Department of Water Resources; and representatives of local and State health officials.

What is the best way to use the supply of clean and gray water available to your household?

1. The first emphasis of household management of water supplies should be the use of existing water conservation methods. The Department of Water Resources and your local water agencies have this information readily available.

2. Water caught in containers while waiting for bathing or sink water to heat before use is not considered waste water and does not require special precautions for its use.

3. It is recommended that you first use gray water for flushing toilets. This is the only recommended use for gray water in the house. The water should be poured directly in the toilet bowl and not the tank. A drop of water pressure can draw water from the tank back into the main pipes and contaminate your clean water supply. Gray water should be used in the toilet tank only if the water inlet pipe to the toilet is disconnected. The quantity of fresh water you save by using gray water this way could be applied, for example, to your vegetable garden.

4. If you find that your household generates more waste water than you need to flush toilets and you still are short on clean water supplies you may want to use the gray water for your outdoor watering needs. Consider the quality of different waste waters before you decide how to use your gray water supply. Kitchen waste water originates from food preparation and dishwashing, and so this source of gray water often contains food residues, greases, detergents, and scouring bleach. Because grease and food substances can attract insects and rodents, and grease and detergents can be harmful to soils, kitchen sink waste water is the least preferred source for irrigation water. The next sources of gray water which require more cautious use are laundry wastes containing body oils, dirt, detergent, and other contaminants, followed by bathroom sink waste water from tooth brushing, hand/face washing and shaving. The order of preference then for the selection of gray water for landscape use is bath water, bathroom sink, washing machine or clothes washing, dish washing, and kitchen sink water. The use of rinse water from clothes or dishes is preferable over water used in the wash process that contains the most soap, dirt, and grease.

5. Kitchen sink water can be an acceptable source of gray water if you minimize its food and grease content. If you are catching water in your sink to reuse, the use of your garbage disposal should be discontinued because the lower than normal flow of water may result in eventual clogging of sewage pipes with food residue. Scrape your dishes thoroughly into your garbage before washing and put a pea trap in your sink if you are replacing your garbage grinder.

6. Bacteria and viruses are present in large numbers in wash water that has come in contact with diapers. While the immediate family may not be concerned by their exposure to this water, concern should be given to neighbors if this water source is used outside. Particular care should be given to the use of gray water where it is being applied commonly in yards of populated neighborhoods because of the greater chance of spreading communicable disease. Rely on your common sense to guide your decisions on using gray water. If someone in your household is sick, special care is required to prevent the spread of communicable disease.

7. Ponding of gray water on the ground must not occur in order to avoid mosquito and fly breeding. Runoff of gray water from your property is not allowable under any circumstances.

8. It is best to restrict use of gray water on the landscape to ornamental plants. If you do not have clean water for use on your vegetable garden, use gray water for higher growing, bush, and vine plants which are nonroot crops such as beans, corn and tomatoes. Avoid contact with the edible portion of the plant. Gray water should not be used on root crops such as carrots and radishes.

How do you collect and transport gray water from its source in order to use it?

The obvious method is to collect the waste water from the tub, sinks, washing machine drain basins or outlets, etc., in buckets and hand carry to the toilet or garden. If you disconnect a drain pipe to collect the waste water, the sewer inlet must be capped or be left with water in it to prevent the escape of methane gases from your sewer system. Using the gray water immediately can be preferable because it avoids the problem of storage. This prevents the water from going septic, creating odors, and attracting flies. The disadvantage of not storing the gray water is that it does not allow for the possibility of diluting more soap or greasy sources with cleaner supplies, and eliminates the use of filtering systems. It also does not provide for the even and thorough irrigation which is often necessary in order to be of value to the plants. Storage tanks should be out of the reach of children and tightly covered. In most homes you can take advantage of gravity to move the waste water through a hose down to a storage tank or for immediate use on the landscape. If gravity feed is not possible, you can purchase a pump for a cost between approximately $30 to $125. Filter systems can involve such methods as running the water through a hay filled drum or through a drum with layers of sand, pea gravel, medium and large gravel. The latter system will collect scum on the top of the sand that will require removal. If you use hay, compost it after a week's use and place new hay in the drum. Other filter systems have employed stocking or canvass bags which intercept the water before it is applied to the ground. Again, these filters need to be regularly cleaned or replaced.

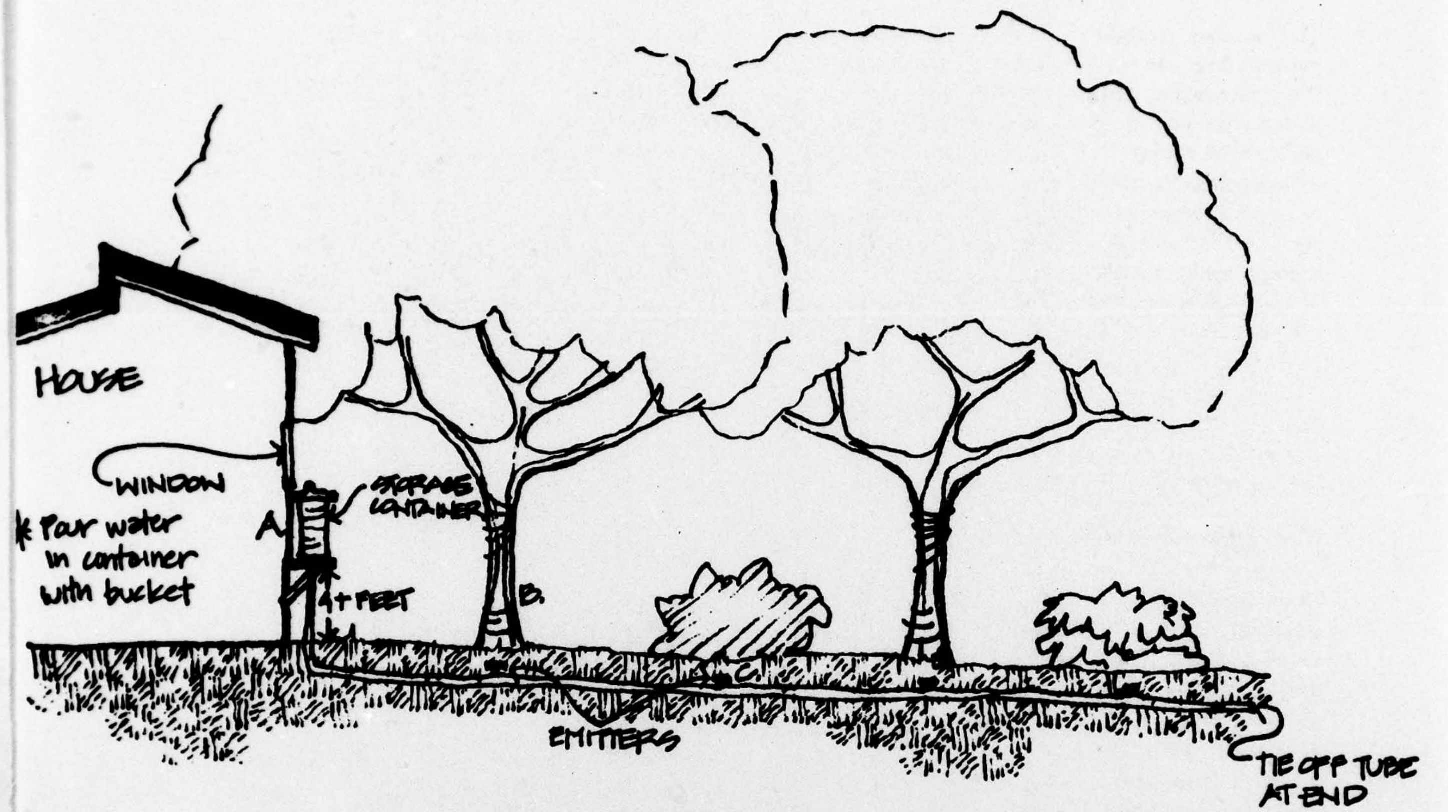
What is the best way to apply gray water to the landscape?

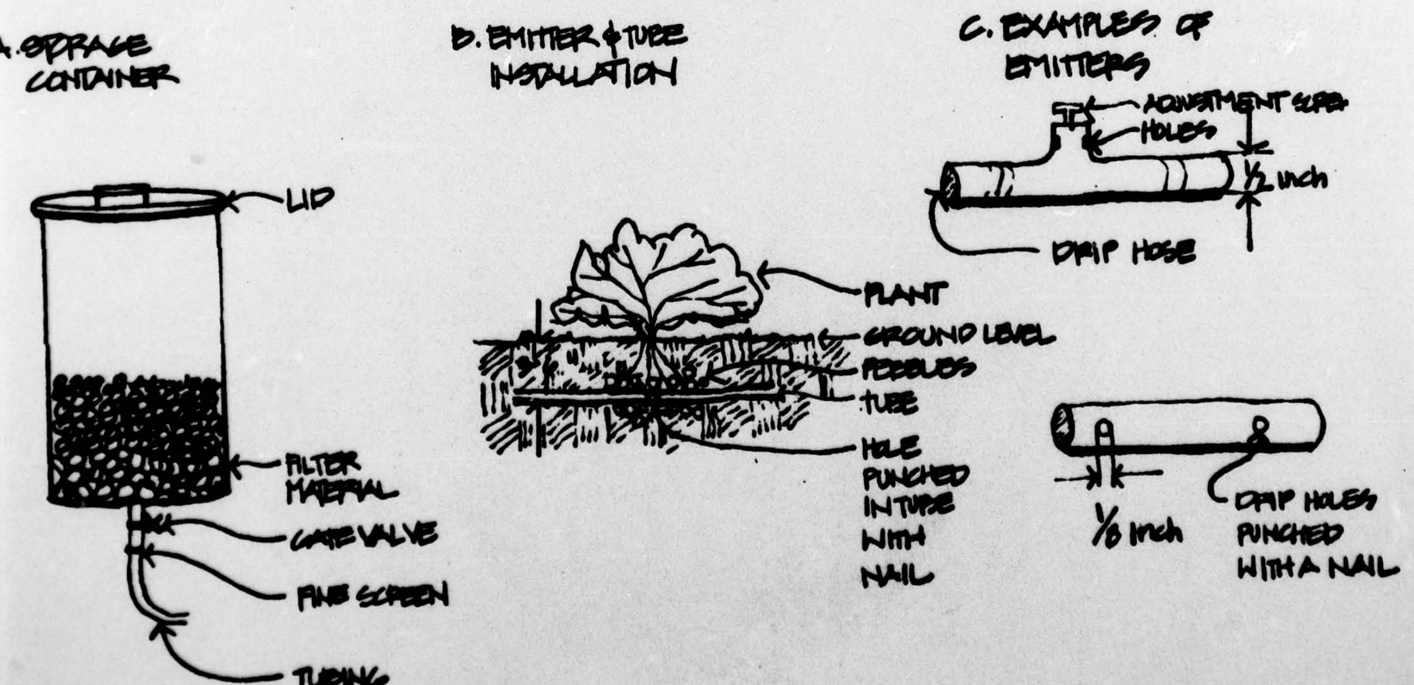
Never apply gray water with an overhead sprinkler. The best way to apply the water, whether you are using a bucket, hose, drip tubing, tile, or ditch system is under the cover of ground or under mulch such as wood chips and pebbles. An irrigation ditch can be lined with mulch materials which can cover tubing or bucket delivered water as it soaks into the ground. Many people are starting to acquire drip-irrigation systems for watering landscapes which you may want to try using to deliver gray water. The systems consists of ½-inch tubing with small holes or emitters that release water slowly from the tube to the soil. This irrigation method avoids surface evaporation, runoff and ponding. Do not use a drip system with the micro-tubing because the possibility of clogging these small drip tubes is very likely. For purposes of using gray water you may want to punch holes in some tubing with a nail so that the holes are slightly bigger than those in the conventionally designed drip hoses. An example of a simple underground distribution system is shown on the following page.

save water

DWR

A system using underground tubing for gray water application must use well filtered water in order to prevent clogging.





Local Health Departments or University Extension Offices should be contacted for the information they have concerning systems for underground gray water application.

APPENDIX D

SEPTIC TANK MAINTENANCE

General Information on Septic Tanks

Cleaning.—Septic tanks should be cleaned before too much sludge or scum is allowed to accumulate. If either the sludge or scum approaches too closely to the bottom of the outlet device, particles will be scoured into the disposal field and will clog the system. Eventually, when this happens, liquid may break through to the ground surface, and the sewage may back up in the plumbing fixtures. When a disposal field is clogged in this manner, it is not only necessary to clean the tank, but it also may be necessary to construct a new disposal field.

The tank capacities given in Table 5 on page 29 will give a reasonable period of good operation before cleaning becomes necessary. There are wide differences in the rate that sludge and scum will accumulate from one tank to the next. For example, in one case out of 20, the tank will reach the danger point, and should be cleaned, in less than 3 years. *Tanks should be inspected at least once a year and cleaned when necessary.*

Although it is difficult for most homeowners, actual inspection of sludge and scum accumulations is the only way to determine definitely when a given tank needs to be pumped. When a tank is inspected, the depth of sludge and scum should be measured in the vicinity of the outlet baffle. The tank should be cleaned if either: (a) The bottom of the scum mat is within approximately 3 inches of the bottom of the outlet device; or (b) sludge comes within the limits specified in Table 6 (see Figure 18).

Table 6.—Allowable sludge accumulation

Liquid capacity of tank, gallons*	Liquid depth			
	2½ feet	3 feet	4 feet	5 feet
	Distance from bottom of outlet device to top of sludge, inches			
750	5	6	10	13
900	4	4	7	10
1,000	4	4	6	8

* Tanks smaller than the capacities listed will require more frequent cleaning.

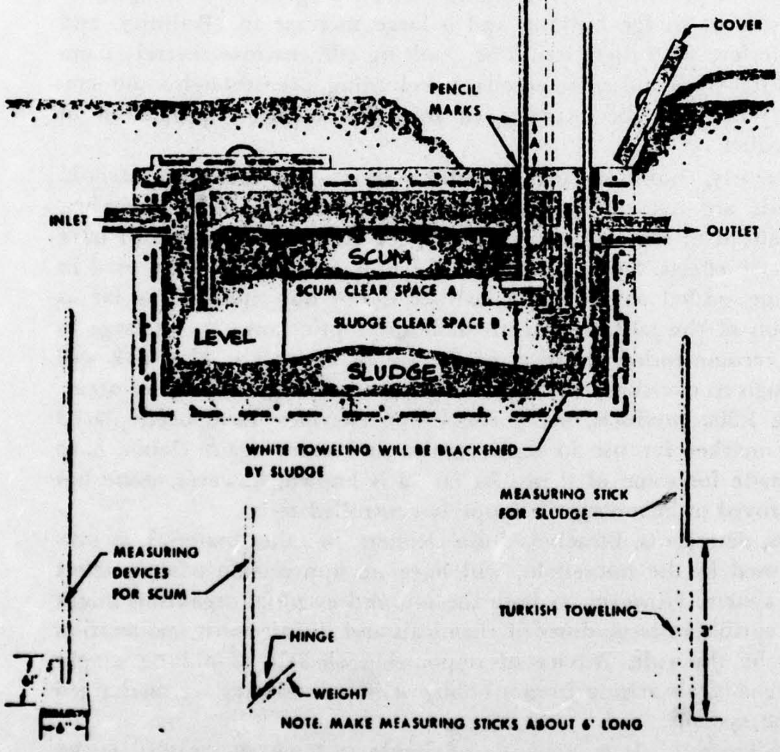
Scum can be measured with a stick to which a weighted flap has been hinged, or with any device that can be used to feel out the bottom of the scum mat. The stick is forced through the mat, the hinged flap falls into a horizontal position, and the stick is raised until resistance from the bottom of the scum is felt. With the same tool, the distance to the bottom of the outlet device can be found (see Figure 18).

A long stick wrapped with rough, white toweling and lowered to the bottom of the tank will show the depth of sludge and the liquid depth of the tank. The stick should be lowered behind the outlet device to avoid scum particles. After several minutes, if the stick is carefully removed, the sludge line can be distinguished by sludge particles clinging to the toweling.

In most communities where septic tanks are used, there are firms which conduct a business of cleaning septic tanks. The local health department can make suggestions on how to obtain this service.

Cleaning is usually accomplished by pumping the contents of the tank into a tank truck. *Tanks should not be washed or disinfected after pumping.* A small residual of sludge should be left in the tank for seeding purposes. The material removed may be buried in uninhabited places or, with permission of the proper authority, emptied into a sanitary sewer system. It should never be emptied into storm drains or discharged directly into any stream or watercourse. Methods of disposal should be approved by the health authorities.

When a large septic tank is being cleaned, care should be taken not to enter the tank until it has been thoroughly ventilated and gases have been removed to prevent explosion hazards or asphyxiation of the workers. Anyone entering the tank should have one end of a stout rope tied around his waist, with the other end held above ground



NOTE: CLEAN WHEN A IS 3" OR LESS, AND WHEN B IS WITHIN THE LIMITS SPECIFIED IN TABLE 6.

Figure 18.—Devices for measuring sludge and scum.

by another person strong enough to pull him out if he should be overcome by any gas remaining in the tank.

Grease Interceptors.—Grease interceptors (grease traps) are not ordinarily considered necessary on household sewage disposal systems. The discharge from a garbage grinder should never be passed through them. The septic tank capacities recommended in this manual are sufficient to receive the grease normally discharged from a home.

Chemicals.—The functional operation of septic tanks is not improved by the addition of disinfectants or other chemicals. In general, the addition of chemicals to a septic tank is not recommended. Some proprietary products which are claimed to "clean" septic tanks contain sodium hydroxide or potassium hydroxide as the active agent. Such compounds may result in sludge bulking and a large increase in alkalinity, and may interfere with digestion. The resulting effluent may severely damage soil structure and cause accelerated clogging, even though some temporary relief may be experienced immediately after application of the product.

Frequently, however, the harmful effects of ordinary household chemicals are overemphasized. Small amounts of chlorine bleaches, added ahead of the tank, may be used for odor control and will have no adverse effects. Small quantities of lye or caustics normally used in the home, added to plumbing fixtures is not objectionable as far as operation of the tank is concerned. If the septic tanks are as large as herein recommended, dilution of the lye or caustics in the tank will be enough to overcome any harmful effects that might otherwise occur.

Some 1,200 products, many containing enzymes, have been placed on the market for use in septic tanks, and extravagant claims have been made for some of them. As far as is known, however, none has been proved of advantage in properly controlled tests.

Soaps, detergents, bleaches, drain cleaners, or other material, as normally used in the household, will have no appreciable adverse effect on the system. However, as both the soil and essential organisms might be susceptible to large doses of chemicals and disinfectants, moderation should be the rule. Advice of responsible officials should be sought before chemicals arising from a hobby or home industry are discharged into the systems.

Miscellaneous.—It is generally advisable to have all sanitary wastes from a household discharge to a single septic tank and disposal system. For household installations, it is usually more economical to provide a single disposal system than two or more with the same total capacity. Normal household waste, including that from the laundry, bath, and kitchen, should pass into a single system.

Roof drains, foundation drains and drainage from other sources producing large intermittent or constant volumes of clear water should not be piped into the septic tank or absorption area. Such large volumes of water will stir up the contents of the tank and carry some of the

solids into the outlet line; the disposal system following the tank will likewise become flooded or clogged, and may fail. Drainage from garage floors or other sources of oily waste should also be excluded from the tank.

Toilet paper substitutes should not be flushed into a septic tank. Paper towels, newspaper, wrapping paper, rags, and sticks may not decompose in the tank, and are likely to lead to clogging of the plumbing and disposal system.

Waste brines from household water softener units have no adverse effect on the action of the septic tank, but may cause a slight shortening of the life of a disposal field installed in a structured clay type soil.

Adequate venting is obtained through the building plumbing if the tank and the plumbing are designed and installed properly. A separate vent on a septic tank is not necessary.

A chart showing the location of the septic tank and disposal system should be placed at a suitable location in dwellings served by such a system. Whether furnished by the builder, septic tank installer, or the local health department, the charts should contain brief instructions as to the inspection and maintenance required. The charts should assist in acquainting homeowners of the necessary maintenance which septic tanks require, thus forestalling failures by assuring satisfactory operation. The extension of *the manholes or inspection* holes of the septic tank to within 8 inches of the ground surface will simplify maintenance and cleaning.

Abandoned septic tanks should be filled with earth or rock.

Source: Manual of Septic Tank Practice, U.S. Department of Commerce, National Center for Urban Industrial Health, Cincinnati, Ohio, 1967.

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EMERGENCY SEWAGE PROCEDURES DURING CRISIS RELOCATION
SSI 7720-4
Scientific Service, Inc., Redwood City, CA
November 1978 260 pp.
Contract No. DCPA01-77-C-0239, Work Unit 2422E
UNCLASSIFIED

This work was conducted in support of Crisis Relocation Planning (CRP), a comprehensive effort by the Defense Civil Preparedness Agency to prepare contingency plans for the relocation of population from high-risk areas to protect them from the combined blast and radiation effects of nuclear weapons. This program considered one of the most important support functions—sewage treatment—in the host areas.

Part I is the technical report which provides background material, references and the rationale behind the development of the manual which is Part II. Also discussed is the field testing phase including observations and conclusions obtained from this testing.

Part II is a sewage treatment operations manual for Crisis Relocation (CR). This manual is organized around the various treatment processes. First there is a brief description of each process; then, to aid the plant operators, worksheets have been set up to detail each individual calculation that is needed to estimate performance of the different processes and identify trouble areas within the plant. A brief worksheet description precedes each worksheet. The worksheets are arranged to provide a step-by-step analysis of present operating conditions, the projected operational loadings during CR, and the effect of these increased loadings on process operations. Following each worksheet there is a discussion of operational problems likely to occur during CR, followed by a detailed troubleshooting guide and brief discussion of laboratory tests that will be most useful in analyzing potential problems associated with CR.

Following the sections on treatment processes, a summary worksheet is provided which helps the user categorize the severity of potential problems associated with each process for a particular plant. The next section describes a variety of load reduction measures which can be implemented depending on the nature of the anticipated problem. The manual concludes with some sample forms dealing with various logistical arrangements pertinent to CR.

Part III deals with the disposal of wastes in non-sewered areas. This will be a significant problem during CR since many of the relocation host areas will not be serviced by a sewage treatment plant. Topics discussed include various types of disposal, public health issues, and proper disposal and control measures.

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